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(57) [Abstract]　　(There is an amendment.)

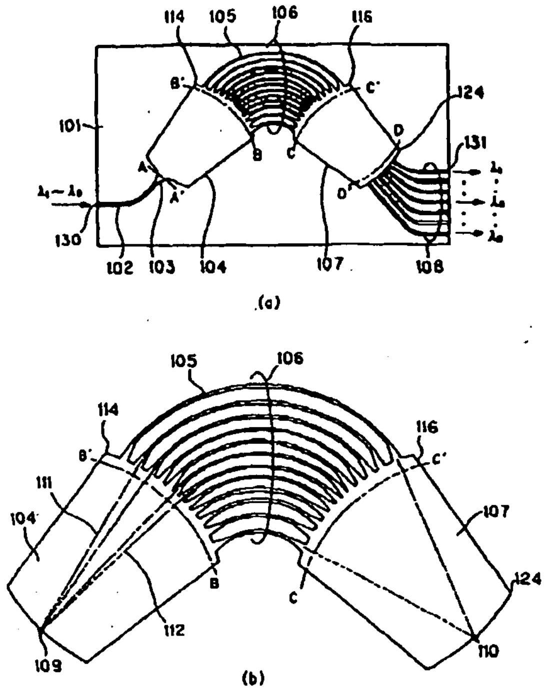
【課題】　光源の波長変動に対する損失変動が小さく、かつ安定した光信号の合分波が可能な光波長合分波器を提供する。

[Problem] Light wavelength divider/coupler where combination amount wave of light signal to which theloss fluctuation for wavelength fluctuation of light source is small, atthe same time stabilizes is possible is offered.

【解決手段】アレイ導波路回折格子１０６と、前記入力用チャネル導波路１０２及びアレイ導波路回折格子１０６を接続する扇形の入力側スラブ導波路１０４と、前記出力用チャネル導波路１０８及び前記アレイ導波路回折格子１０６を接続する扇形の出力側スラブ導波路１０７とを設け、前記入力側スラブ導波路１０４及び前記アレイ導波路回折格子１０６の接続部、又は前記出力側スラブ導波路１０７及び前記アレイ導波路回折格子１０６の接続部のうちの少なくとも一方において、アレイ導波路格子１０６を構成する各チャネル導波路１０５の中心軸と、それぞれ隣接するチャネル導波路１０５の中心軸との間隔を、全チャネル導波路１０５にわたって徐々に変化させる。

[Means of Solution] Array waveguide diffraction grating 106, channel waveguide 102 for front entry power and connects array waveguide diffraction grating 106 input side slab waveguide 104 ofthe fan shape which. channel waveguide 108 for aforementioned output and output side slab waveguide 107 of fan shapewhich connects aforementioned array waveguide diffraction grating 106 to provide, It changes gradually connector of aforementioned input side slab waveguide 104 and theaforementioned array waveguide diffraction grating 106, in at least one among connector of oraforementioned output side slab waveguide 107 and aforementioned array waveguide diffraction grating 106, spacing of thecenter axis of channel waveguide 105 which is adjacent with center axis of each channel waveguide 105which forms array waveguide grating

106, respectively, over all channel waveguide 105.



【特許請求の範囲】

[Claim(s)]

【請求項１】　基板上に、１本以上の入力用チャネル導波路と、１本以上の出力用チャネル導波路と、導波路長を最短なものから最長なものへ所定の長さずつ順次長く設定した複数本のチャネル導波路で構成したアレイ導波路回折格子と、前記入力用チャネル導波路及びアレイ導波路回折格子を接続する扇形の入力側スラブ導波路と、前記出力用チャネル導波路及び前記アレイ導波路回折格子を接続する扇形の出力側スラブ導波路とを備えた光波長合分波器であって、

[Claim 1] To on substrate, channel waveguide for input of one or more, channel waveguide and waveguide length for output of one or more shortest fromthe thing longest each specified length being a light wavelength divider/coupler which has with thearray waveguide diffraction grating and channel waveguide for front entry power and input side slab waveguide of fan shapewhich connects array waveguide diffraction grating and channel waveguide for aforementioned outputand output side slab waveguide of fan shape which which connects aforementionedarray waveguide diffraction grating are formed with multiple channel waveguide which sequential long is set to thething,

前記入力側スラブ導波路及び前記アレイ導波路回折格子の接続部、又は前記出力側スラブ導波路及び前記アレイ導波路回折格子の接続部のうちの少なくとも一方において、前記アレイ導波路格子を構成する各チャネル導波路の中心軸と、それぞれ隣接するチャネル導波路の中心軸との間隔を、全チャネル導波路にわたって徐々に変化させてなることを特徴とする光波長合分波器。

Changing gradually connector of aforementioned input side slab waveguide and theaforementioned array waveguide diffraction grating, in at least one among connector of oraforementioned output side slab waveguide and aforementioned array waveguide diffraction grating, spacing of thecenter axis of channel waveguide which is adjacent with center axis of each channel waveguidewhich forms aforementioned array waveguide grating, respectively, over all channel waveguide,the light wavelength divider/coupler which designates that it becomes as feature.

【請求項２】　前記入力側スラブ導波路の前記接続部及

[Claim 2] In aforementioned connector of aforementioned in

び前記出力側スラブ導波路の前記接続部において、前記アレイ導波路回折格子を構成する前記チャネル導波路を、前記入力スラブ導波路及び前記出力側スラブ導波路に沿ってそれぞれ放射状に配置し、前記各チャネル導波路の中心軸と、それぞれ隣接するチャネル導波路の中心軸との間の所定の基準点に対する角度を、全チャネル導波路にわたって徐々に変化させてなる請求項１に記載の光波長合分波器。

put side slab waveguide and aforementionedconnector of aforementioned output side slab waveguide putting. Aforementioned channel waveguide which forms aforementioned array waveguide diffraction grating.changing gradually angle for specified reference point with center axis of channel waveguidewhich arranges respectively in radial alongside front entrypower slab waveguide , and aforementioned output side slab waveguide is adjacent with center axisof aforementioned each channel waveguide, respectively, over all channel waveguide, thelight wavelength divider/coupler which it states in explanation/learning seeking Claim 1 whichbecomes.

【請求項３】　前記アレイ導波路回折格子を構成する前記チャネル導波路の本数をＮ、前記各チャネル導波路の番号をｉ、予め定めた基準のチャネル導波路の番号ｊとしたとき、前記入力側スラブ導波路又は前記出力側スラブ導波路の前記接続部における第ｉ番目の前記チャネル導波路と第ｉ＋１番目の前記チャネル導波路との間の前記所定の基準点に対する角度Δθｉを、下記式（１）に示すように、徐々に変化させてなる請求項２に記載の光波長合分波器。

[Claim 3] Number of aforementioned channel waveguide which forms aforementionedarray waveguide diffraction grating N, When number of aforementioned each channel waveguide i, making thenumber j of channel waveguide of standard which is decided beforehand, as shownthe angle i for aforementioned specified reference point with aforementioned channel waveguideof i'th th in aforementioned input side slab waveguide or aforementioned connectorof aforementioned output side slab waveguide and aforementioned channel waveguide of i'th + first,in below-mentioned Formula (1), changing gradually, light wavelength divider/coupler which itstates in Claim 2 which becomes.

$$\Delta\theta i = \Delta\theta j \cdot \{1 + \Sigma A_k \cdot |i - j|^k\} \quad \cdots (1)$$

i= j * {1 + Ak * |i - j|k } ...(1)

（式（１）中、A_kは定数であり、ｋは１～Ｎの整数である。）

(Formula (1) In, Ak is constant, k is integer of 1 to N.)

【請求項４】　前記式（１）において、所定の定数Ａの範囲を－０．００１≦A_k≦０．００１（ｋは１～Ｎの整数である）とした請求項３に記載の光波長合分波器。

[Claim 4] In aforementioned Formula (1), range of specified c onstant A - 0,001 Ak 0,001 (k is integer of 1 to N.) with thelight wavelength divider/coupler which is stated in Claim 3 which is done.

【請求項５】　前記式（１）において、前記アレイ導波路回折格子を構成するチャネル導波路の本数（Ｎ）を１とすることにより、前記角度Δθｉを下記式（２）に示すものとした請求項３又は４に記載の光波長合分波器。

[Claim 5] Light wavelength divider/coupler which is stated in Claim 3 or 4 show aforementioned angle iin below-mentioned Formula (2) in aforementioned Formula (1), bydesignating number (N) of channel waveguide which forms aforementionedarray waveguide diffraction grating as 1.

$$\Delta\theta i = \Delta\theta j \cdot \{1 + A_1 \cdot |i - j|\} \quad \cdots (2)$$

i= j * {1 + Al * |i - j|} ...(2)

（式（２）中、A_1は定数であり、$A_1 \neq 0$である。）

(Formula (2) In, Al is constant, is Al 0.)

【発明の詳細な説明】

[Description of the Invention]

【０００１】

[0001]

【発明の属する技術分野】本発明は、光波長合分波器に

[Technological Field of Invention] This invention regards light

関し、特に、光源の波長変動に対する損失変動が小さく、かつ安定した光信号の合分波が可能な光波長合分波器に関する。

wavelength divider/coupler , it regards light wavelength divider. coupler where thecombination amount wave of light signal to which especially, lossfluctuation for wavelength fluctuation of light source is small, at thesame time stabilizes is possible.

【０００２】

【従来の技術】光波長多重通信において、波長の異なる複数の光信号の合波又は分波（合分波）をする光波長合分波器としてアレイ導波路回折格子が有望視され、種々提案されている（特開平４－１１６６０７号公報、特開平４－１６３４０６４、特開平４－２２０６２４号公報、特開平４－３２６３０８４号公報、特開平５－１５７９２０号公報）。特に、通過帯域特性を平坦化したアレイ導波路回折格子型光波長合分波器は、光源の波長変動等に対する挿入損失の変動が小さく、安定した光信号の合分波が可能であるため、光波長多重通信に有用なデバイスとして期待されている（米国特許第５４１２７４４号）。

[0002]

[Prior Art] That array waveguide diffraction grating is promising in light wavelength multiple communication, as light wavelength divider/coupler which does thecombination wave or amount wave (Combination amount wave) of light signal of plural wherethe wavelength differs it is considered, various is proposed (Japan Unexamined Patent Publication Hei 4 - 116607 disclosure , Japan Unexamined Patent Publication Hei 4 - 1634064, Japan Unexamined Patent Publication Hei 4 - 220624 disclosure , Japan Unexamined Patent Publication Hei 4 - 3263084 disclosure and Japan Unexamined Patent Publication Hei 5 - 157920 disclosure). Especially, because combination amount wave of light signal to whichas for array waveguide diffraction grating type light wavelength divider/coupler which passing domain characteristic planarization is done,fluctuation of insertion loss for wavelength fluctuation etc of light source issmall, stabilizes is possible, it is expected to light wavelength multiple communication as theuseful device (U. S. Patent No. 5412744 number).

【０００３】図７は、従来のアレイ導波路回折格子型光波長合分波器を模式的に示す説明図である。ここでは、一例として、９つの光信号λ_1～λ_9（$\lambda_1 < \lambda_2 < \cdots < \lambda_8 < \lambda_9$）を合分波するための光波長合分波器を示す。図７に示すように、従来の光波長合分波器は、基板２０１上に、入力導波路２０２と、入力側スラブ導波路２０４と、長さが後述するΔＬずつ異なる複数のチャネル導波路２０５で形成したアレイ導波路回折格子２０６と、出力側スラブ導波路２０７と、９本の出力導波路２０８とから形成されている。また、入力導波路２０２と入力側スラブ導波路２０４の接続部には損失波長特性の通過域特性を平坦化するためのモード変換部２０３が形成されている。

[0003] Figure 7 is explanatory diagram which shows conventional array waveguide diffraction grating type light wavelength divider/coupler in schematic. Here, 9 horn light signal 1 to 9(1< 2<..< 8< 9) light wavelength divider/coupler in order combination amountwave to do is shown as one example. As shown in Figure 7, conventional light wavelength divider/coupler, on substrate 201, at a time inputwaveguide 202 and L which input side slab waveguide 204 and length mention later isformed from output waveguide 208 of array waveguide diffraction grating 206 and output side slab waveguide 207 and 9book which were formed with channel waveguide 205 of plural which differs. In addition, mode converting part 203 in order planarization to do passing limitscharacteristic of loss wavelength characteristic to input waveguide 202 and connector of input side slab waveguide 204is formed.

【０００４】図８は、従来のアレイ導波路回折格子型光波長合分波器の所定部位における光信号の電界分布を模式的に示す説明図であり、図８（ａ）は、モード変換部２０３のＥ－Ｅ′における光信号の電界分布２０９、図８（ｂ）は、アレイ導波路回折格子入射端２１０のＦ－Ｆ′における電界分布２１１、図８（ｃ）は、アレイ導波路回折格子出射端２１２のＧ－Ｇ′での電界分布２１

[0004] As for Figure 8, it is a explanatory diagram which shows electric field distribution of light signal inthe specified site of conventional array waveguide diffraction grating type light wavelength divider/coupler in schematic, as for Figure 8 (a), theelectric field distribution 209 of light signal in E - E' of mode converting part 203, as for Figure 8 (b), theelectric field distribution 211 and Figure 8 (c) in F - F' of array waveguide

3をそれぞれ示す。

diffraction grating incident edge 210 show electric field distribution 213 with theG - G' of array waveguide diffraction grating emitting end 212 respectively.

【0005】図9は、従来のアレイ導波路回折格子型光波長合分波器の所定部位における光信号の位相分布を模式的に示す説明図であり、図9(a)、図9(e)、図9(f)は、アレイ導波路回折格子出射端212のG－G' での光信号λ_1、λ_5、λ_9のそれぞれの位相分布214、215、216を示す。

[0005] As for Figure 9, it is a explanatory diagram which shows phase distribution of light signal inthe specified site of conventional array waveguide diffraction grating type light wavelength divider/coupler in schematic, Figure 9 (a), Figure 9 (e)and Figure 9 (f), light signal 1 with G - G' of array waveguide diffraction grating emitting end 212, show therespective phase distribution 214,215,216 of 5 and 9.

【0006】図10は、従来のアレイ導波路回折格子型光波長合分波器の所定部位における光信号の位相分布の差を模式的に示す説明図であり、図10(a)及び図10(b)は、光信号λ_1、λ_9の位相面214、216とλ_5の位相面215とのそれぞれの位相分布の差217、218を示す。

[0006] As for Figure 10, it is a explanatory diagram which show s difference of thephase distribution of light signal in specified site of conventional array waveguide diffraction grating type light wavelength divider/coupler in schematic,the Figure 10 (a) and Figure 10 (b), show difference 217,218 of respectivephase distribution of phase surface 214,216 of light signal 1 and 9 and thephase surface 215 of 5.

【0007】図11は、従来のアレイ導波路回折格子型光波長合分波器の集光面219のH－H' における光信号λ_1、λ_5、λ_9の電界分布220、221、222を模式的に示す説明図である。

[0007] As for Figure 11, it is a explanatory diagram which show s electric field distribution 220,221,222 of light signal 1 ,the 5 and 9 in H - H' of light collection surface 219 of the conventional array waveguide diffraction grating type light wavelength divider/coupler in schematic.

【0008】以下、図7を用い、かつ適宜他図を参照して、従来の光合分波器の作用を説明する。なお、アレイ導波路回折格子206を構成するチャネル導波路205の隣接間の導波路長差ΔLは、下記式(3)で設計されているものとする。

[0008] Below, making use of Figure 7, at same time referring to asneeded other figure, you explain action of conventional optical divider/coupler. Furthermore , waveguide long difference L between theadjacent of channel waveguide 205 which forms array waveguide diffraction grating 206 are designed with thebelow-mentioned Formula (3).

$\Delta L = 2 \cdot m \cdot \pi / \beta(\lambda_5)$ … (3)

L=2 * m * / (5) ... (3)

(式(3)中、mは回折次数(正の整数)を示し、$\beta(\lambda_5)$は光信号λ_5に対するチャネル導波路の伝般定数を示す。)

(Formula (3) In, m shows diffraction degree (positive integer), (5) shows transmissiongeneral constant of channel waveguide for light signal 5.)

【0009】入力導波路202から入射された光信号λ_1～λ_9は、モード変換部203、入カスラブ導波路204、アレイ導波路回折格子205、出力スラブ導波路207、出力導波路208の順で伝搬する。

[0009] From input waveguide 202 light signal 1 to 9 which incidence is done, mode converting part 203 andthe input slab waveguide 204, array waveguide diffraction grating 205 and output slab waveguide 207, propagation does inorder of output waveguide 208.

【0010】図8(a)に示すように、モード変換部203のE－E' における光信号の電界分布209は、左右対称の双峰状である。

[0010] As shown in Figure 8 (a), electric field distribution 209 of light signal in E - E' of the mode converting part 203 is bimodal condition of left-right symmetry.

【0011】図8(b)に示すように、入力スラブ導波路204のアレイ導波路回折格子206の入射端210のF－F' における電界分布211は、回折の効果で極

[0011] As shown in Figure 8 (b), electric field distribution 211 in F - F' of incident edge 210 of thearray waveguide diffraction grating 206 of input slab waveguide 204 becomes distribution

大値，極小値をもつ分布となる。アレイ導波路回折格子の入射端２１０のＦ－Ｆ’において、光信号は分割され、各チャネル導波路２０６を入射・伝搬する。

which has maximum value and extremely small value with effect of diffraction. In F - F' of incident edge 210 of array waveguide diffraction grating, light signal is divided, theincident * propagation does each channel waveguide 206.

【００１２】図８（ｃ）に示すように、アレイ導波路回折格子２０５の終端２１２のＧ－Ｇ’における電界分布２１３は、各信号ともに入射端２１０のＦ－Ｆ’での電界分布２１１を再現する。

[0012] As shown in Figure 8 (c), each both signal electric field distribution 211 with F - F' of theincident edge 210 reproduction it does electric field distribution 213 in G - G' of terminal 212 of the array waveguide diffraction grating 205.

【００１３】図９（ａ）、（ｂ）、（ｃ）に示すように、終端２１２のＧ－Ｇ’における光信号λ_1～λ_9の位相面２１４は、光信号によって異なっている。ここで、前記式（３）より、光信号λ_5の位相面２１５は左右対称となり、他の光信号の位相面は、アレイ導波路回折格子終端２１９のＨ－Ｈ’に対して、その伝搬定数に応じた傾きを生じる。

[0013] As shown in Figure 9 (a), (b) and (c), phase surface 214 of light signal 1 to 9 in G - G' of terminal 212 differs depending upon light signal. Here, from aforementioned Formula (3), phase surface 215 of the light signal 5 becomes as for phase aspect of other light signal, left-right symmetry,the slope which responds to propagation constant vis-a-vis H - H' of the array waveguide diffraction grating terminal 219, causes.

【００１４】図１０に示すように、位相差はアレイ導波路回折格子２０６のチャネル導波路２０５において連続的に変化している。各光信号は、出力スラブ導波路２０７において、この傾きに応じた方向に伝搬する。したがって、各光信号は出力スラブ導波路２０７の集光面２１９の異なる点Y_1～Y_9（図示せず）にそれぞれ集光する。

[0014] As shown in Figure 10, phase shift has changed in continuous in channel waveguide 205of array waveguide diffraction grating 206. Each light signal, in direction which responds to this slope in theoutput slab waveguide 207, propagation it does. Therefore, each light signal light collection makes respectively point Y 1 to Y9 (not shown) where thelight collection surface 219 of output slab waveguide 207 differs.

【００１５】ここで、図１１に示すように、集光面２１９のＨ－Ｈ’における各信号の電界分布２２０，２２１，２２２は出力スラブ導波路２０７の収差等の影響を受ける。光信号λ_5の電界分布２２１はモード変換部２０３の電界分布２０９を再現して左右対称の双峰状となるものの、信号λ_1、λ_9の電界分布２２０、２２１は左右非対称となる。非対称は、おもに出力スラブ導波路２０７の収差が原因であるため、集光面２１９のＨ－Ｈ’の端に集光する光信号ほど大きくなる。集光面２１９のＨ－Ｈ’において各信号は、各出力導波路２０８に入射、伝搬し、出力端２２３から別々に取り出すことができる。

[0015] As here, shown in Figure 11, electric field distribution 220,221,222 of each signal in H - H' ofthe light collection surface 219 receives aberration or other influence of outputslab waveguide 207. As for electric field distribution 221 of light signal 5 reproduction doing electric field distribution 209 of mode converting part 203,bimodal condition of left-right symmetry and, electric field distribution 220,221 of signal 1 and 9 becomes left and right asymmetry. asymmetry, because aberration of output slab waveguide 207 is cause mainly, about light signal which light collection is done becomes large in edge of theH - H' of light collection surface 219. Each signal, incidence and propagation does in each output waveguide 208 in theH - H' of light collection surface 219, it is possible to remove from the output terminal 223 separately.

【００１６】図１２は、従来のアレイ導波路回折格子型光波長合分波器の損失波長特性２２４、２２５，２２６，２２７を模式的に示す説明図である。

[0016] Figure 12 is explanatory diagram which shows loss wavelength characteristic 22 4, 2 25,226,227 of conventional array waveguide diffraction grating typelight wavelength divider/coupler in schematic.

【００１７】図１１及び図１２に示すように、各出力導波路２０８の挿入損失は、集光面における光信号の電界分布２２０，２２１，２２２と、各出力導波路２０８の固有モードの重畳積分で決定される。光信号の電界分布２２０，２２１，２２２が、波長に応じて集光面２１９のＨ－Ｈ’上を移動する。電界分布形状も、光信号の集光位置がY_5近傍から離れるにしたがって非対称となる

[0017] Way it shows in Figure 11 and Figure 12, as for insertion loss of each output waveguide 208, it is decided with electric field distribution 220,221,222 of light signal in light collection aspect and superimpositionintegral calculus of peculiar mode of each output waveguide 208. electric field distribution 220,221, 222 of light signal, moves on H - H' of light collection surface 219according to wavelength. Also electric field distribution

、集光位置がY_5近傍では、電界分布形状２２１も左右対称に近いため、波長がわずかに変動しても、挿入損失はあまり変化しない。しかし、集光位置がY_1、Y_9近傍では、電界分布形状２２０，２２２が左右非対称であるため、波長が変動すると、挿入損失は大きく変動する。したがって、波長λ_5の出力導波路２０８の損失波長特性２２４は、通過帯域２２７で平坦な特性となるのに対して、波長λ_1及びλ_9の出力導波路の損失波長特性２２５，２２６の通過帯域特性は、傾いた特性とならざるを得なかった。

geometry, light collection position of light signal leaves from Y5 vicinityfollowing, becomes asymmetry. light collection position does not change with Y5 vicinity, because also electric field distribution geometry 221is close to left-right symmetry, wavelength fluctuating barely, as for insertion lossarrow excessively. But, light collection position fluctuates with Y1 ,Y9 vicinity, because electric field distribution geometry 220,222 isthe left and right asymmetry, when wavelength fluctuates, as for insertion losslargely. Therefore, as for loss wavelength characteristic 224 of output waveguide 208 of wavelength 5 ,vis-a-vis becoming planar characteristic with passing domain 227, if as for thepassing domain characteristic of loss wavelength characteristic 225,226 of output waveguide of wavelength 1 andthe 9, characteristic which tilts strainer was not obtained.

【００１８】

【発明が解決しようとする課題】このように、従来の光波長合分波器によると、出力側スラブ導波路の収差等により、損失波長特性の通過帯域特性が平坦にならないので、光源の波長が変動したとき、挿入損失が大きく変化するといった問題があり、必ずしも十分に満足し得るものではなかった。

[0018]

[Problems to be Solved by the Invention] This way, according t o conventional light wavelength divider/coupler, because passing domain characteristic of theloss wavelength characteristic does not become flat depending upon aberration etc ofthe output side slab waveguide, when wavelength of light source fluctuated, there was a problemthat, insertion loss changes largely, it was not something which always itcan be satisfied with fully.

【００１９】従って、本発明の目的は、光源の波長変動に対する損失変動が小さく、かつ安定した光信号の合分波が可能な光波長合分波器を提供することにある。

[0019] Therefore, it is to offer light wavelength divider/coupler where combination amount waveof light signal to which as for objective of this invention, lossfluctuation for wavelength fluctuation of light source is small, at thesame time stabilizes is possible.

【００２０】

【課題を解決するための手段】本発明は、上記目的を達成するため、以下の光波長合分波器を提供するものである。

[0020]

[Means to Solve the Problems] This invention, in order to achie ve above-mentioned objective, is somethingwhich offers light wavelength divider/coupler below .

【００２１】［１］基板上に、１本以上の入力用チャネル導波路と、１本以上の出力用チャネル導波路と、導波路長を最短なものから最長なものへ所定の長さずつ順次長く設定した複数本のチャネル導波路で構成したアレイ導波路回折格子と、前記入力用チャネル導波路及びアレイ導波路回折格子を接続する扇形の入力側スラブ導波路と、前記出力用チャネル導波路及び前記アレイ導波路回折格子を接続する扇形の出力側スラブ導波路とを備えた光波長合分波器であって、前記入力側スラブ導波路及び前記アレイ導波路回折格子の接続部、又は前記出力側スラブ導波路及び前記アレイ導波路回折格子の接続部のうちの少なくとも一方において、アレイ導波路格子を構成する各チャネル導波路の中心軸と、それぞれ隣接するチ

[0021] [1] To on substrate, channel waveguide for input of one or more, channel waveguide for output of one or more, waveguide length shortest fromthing longest to thing at a timethe specified length sequential is formed with multiple channel waveguide which is set long thearray waveguide diffraction grating which, channel waveguide for front entry power and connects array waveguide diffraction grating input side slab waveguide ofthe fan shape which, Being a light wavelength divider/coupler which has with channel waveguide for aforementioned outputand output side slab waveguide of fan shape which connects aforementioned array waveguide diffraction gratingbeing. Changing gradually connector of aforementioned input side slab waveguide and

ャネル導波路の中心軸との間隔を、全チャネル導波路にわたって徐々に変化させてなることを特徴とする光波長合分波器。

theaforementioned array waveguide diffraction grating, in at least one among connector of oraforementioned output side slab waveguide and aforementioned array waveguide diffraction grating, spacing of thecenter axis of channel waveguide which is adjacent with center axis of each channel waveguidewhich forms array waveguide grating, respectively, over all channel waveguide, light wavelength divider/coupler whichdesignates that it becomes as feature.

【0022】［2］前記入力側スラブ導波路の前記接続部及び前記出力側スラブ導波路の前記接続部において、前記アレイ導波路回折格子を構成する前記チャネル導波路を、前記入力スラブ導波路及び前記出力側スラブ導波路に沿ってそれぞれ放射状に配置し、前記各チャネル導波路の中心軸と、それぞれ隣接するチャネル導波路の中心軸との間の所定の基準点に対する角度を、全チャネル導波路にわたって徐々に変化させてなる前記［1］に記載の光波長合分波器。

[0022] [2] In aforementioned connector of aforementioned in put side slab waveguide and aforementionedconnector of aforementioned output side slab waveguide putting, Aforementioned channel waveguide which forms aforementioned array waveguide diffraction grating,changing gradually angle for specified reference point with center axis of channel waveguidewhich arranges respectively in radial alongside front entrypower slab waveguide , and aforementioned output side slab waveguide is adjacent with center axisof aforementioned each channel waveguide, respectively, over all channel waveguide, thelight wavelength divider/coupler which it states in aforementioned [1] which becomes.

【0023】［3］前記アレイ導波路回折格子を構成する前記チャネル導波路の本数をN、前記各チャネル導波路の番号をi、予め定めた基準のチャネル導波路の番号jとしたとき、前記入力側スラブ導波路又は前記出力側スラブ導波路の前記接続部における第i番目の前記チャネル導波路と第i＋1番目の前記チャネル導波路との間の前記所定の基準点に対する角度Δθiを、下記式（1）に示すように、徐々に変化させてなる前記［2］に記載の光波長合分波器。

[0023] [3] Number of aforementioned channel waveguide which forms aforementionedarray waveguide diffraction grating N, When number of aforementioned each channel waveguide i, making thenumber j of channel waveguide of standard which is decided beforehand, as shownthe angle i for aforementioned specified reference point with aforementioned channel waveguideof i'th th in aforementioned input side slab waveguide or aforementioned connectorof aforementioned output side slab waveguide and aforementioned channel waveguide of i'th + first,in below-mentioned Formula (1), changing gradually, light wavelength divider/coupler which itstates in aforementioned [2] which becomes.

$$\Delta\theta i = \Delta\theta j \cdot \{1 + \Sigma A_k \cdot |i - j|^k\} \quad \cdots (1)$$

i= j * {1+ Ak *|i-j|k } ...(1)

（式（1）中、A_kは定数であり、kは1～Nの整数である。）

(Formula (1) In, Ak is constant, k is integer of 1 to N.)

【0024】［4］前記式（1）において、所定の定数Aの範囲を$-0.001 \leq A_k \leq 0.001$（kは1～Nの整数である）とした前記［3］に記載の光波長合分波器。

[0024] [4] In aforementioned Formula (1), range of specified c onstant A - 0,001 Ak 0,001 (k is integer of 1 to N.) with thelight wavelength divider/coupler which is stated in aforementioned [3] which is done.

【0025】［5］前記式（1）において、前記アレイ導波路回折格子を構成するチャネル導波路の本数（N）を1とすることにより、前記角度Δθiを下記式（2）に示すものとした前記［3］又は［4］に記載の光波長合分波器。

[0025] [5] Light wavelength divider/coupler which is stated in a forementioned [3] or [4] show aforementioned angle i in below-mentioned Formula (2) inthe aforementioned Formula (1), by designating number (N) of channel waveguide whichforms aforementioned array waveguide diffraction grating as 1.

$$\Delta\theta i = \Delta\theta j \cdot \{1 + A_1 \cdot |i - j|\} \quad \cdots ($$

i= j * {1 + A1 *|i - j|} ...(2)

2)

（式（2）中、A_1は定数であり、$A_1 \neq 0$である。）

(Formula (2) In. AI is constant, is AI 0.)

【0026】

【発明の実施の形態】以下、本発明の実施の形態を、図面を参照しつつ具体的に説明する。図１は、本発明の光波長合分波器の一実施の形態であるアレイ導波路回折格子型光波長合分波器を模式的に示す説明図であり、図１（ａ）は、その全体図で、図１（ｂ）は、アレイ導波路回折格子部の拡大図である。ここでは、一例として、９つの光信号λ_1～λ_9（$\lambda_1 < \lambda_2 < \cdots < \lambda_8 < \lambda_9$）を合分波するための光波長合分波器を示す。

[0026]

[Embodiment of Invention] While below, embodiment of this invention, referring to drawing, youexplain concretely. Figure 1 is explanatory diagram which shows array waveguide diffraction grating type light wavelength divider/coupler which is aone embodiment of light wavelength divider/coupler of this invention in schematic as for Figure 1 (a), withthe whole diagram, as for Figure 1 (b), is expanded view of array waveguide diffraction grating section. Here, 9 horn light signal 1 to 9(1< 2<...< 8< 9) light wavelength divider/coupler in order combination amountwave to do is shown as one example.

【００２７】図１（ａ）に示すように、基板１０１上に、入力導波路１０２と、入力側スラブ導波路１０４と、最短なものから最長なものへ前記式（３）に示すΔＬの長さずつ順次長く設定したＮ本のチャネル導波路１０５で構成されたアレイ導波路回折格子１０６と、出力側スラブ導波路１０７と、９本の出力導波路１０８とから形成されている。また、入力導波路１０２と入力側スラブ導波路１０４の接続部には、損失波長特性の通過域特性を平坦化するためのモード変換部１０３を形成している。

[0027] As shown in Figure 1 (a), on substrate 101, input waveguide 102 and input side slab waveguide 104 andthe shortest fromthing longest to thing each length of the L which is shown in aforementioned Formula (3) it is formed from theoutput waveguide 108 of array waveguide diffraction grating 106 and output side slab waveguide 107 and 9 book which areformed with channel waveguide 105 of N book which sequential long sets. In addition, mode converting part 103 in order planarization to do passing limitscharacteristic of loss wavelength characteristic, to input waveguide 102 and connector of input side slab waveguide 104is formed.

【００２８】図１（ｂ）に示すように、アレイ導波路格回折格子１０６を構成する各チャネル導波路１０５は、入力スラブ導波路１０４の接続部及び出力導波路１０７の接続部において、入力スラブ導波路１０４及び出力スラブ導波路１０７の基準点１０９，１１０に対して放射状に配置している。各チャネル導波路１０５がそれぞれの隣接するチャネル導波路となす角度Δθは、アレイ導波路回折格子の下側（Ｂ、Ｃ側）から上側（Ｂ　、Ｃ側）に向かって徐々に変化している。ここで、アレイ導波路回折格子１０６の第ｉチャネル導波路が、隣接する第ｉ＋１チャネル導波路とがなす角度Δθｉ１１１は、基準となる第ｊチャネル導波路及びその角度間隔Δθｊ１１２に対して、下記式（４）となるように配置している。

[0028] As shown in Figure 1 (b), it arranges each channel waveguide 105 which forms array waveguidecase diffraction grating 106, in radial in connector of input slab waveguide 104 and connectorof output waveguide 107, vis-a-vis reference point 109, 110 of input slab waveguide 104 and theoutput slab waveguide 107. channel waveguide where each channel waveguide 105 is adjacent each one angle which isformed has changed gradually from underside (B,C side) of array waveguide diffraction grating facingtoward topside (B, C side). Here, i'th channel waveguide of array waveguide diffraction grating 106, in order to become thebelow-mentioned Formula (4) vis-a-vis j channel waveguide and its angle spacing j112 which becomethe standard, has arranged angle i111 which i'th + 1 channel waveguide which is adjacent forms.

$$\Delta\theta i = \Delta\theta j \cdot \{1 + A \cdot |i - j|\} \quad \cdots (4)$$

i= j * {1 + A * |i - j|} ...(4)

（式（４）中、ｉはアレイ導波路格子を構成するチャネル導波路の番号、ｊは基準導波路番号、Ａは定数で、Ａ≠０である。）

(Formula (4) In, as for i number of channel waveguide which forms array waveguide grating, asfor j as for reference waveguide number and A with constant, it is aA 0.)

【００２９】本発明では、アレイ導波路回折格子１０６を構成するチャネル導波路１０５の本数を６０本、所定の導波路番号ｊを３０、この第３０チャネル導波路と第３１チャネル導波路とがなす角度間隔Δθ_{30}を０．２（ｄｅｇ．）とし、定数Ａを０．０００２とした。なお、この定数Ａは、前記式（１）に示すように、値の絶対値が小さいと補正の効果が弱く、逆に大きすぎると補正の効果が強すぎるため、－０．００１から０．００１の範囲とすることが好ましい。

[0029] With this invention, number of channel waveguide 105 which forms array waveguide diffraction grating 106 6 0 and specified waveguide number j 30, this 3rd 0 channel waveguide and angle interval 30 which 3rd 1 channel waveguideforms were designated as 0.2(deg.), constant A was designated as the0.0002. Furthermore , when as for this constant A. as shown in theaforementioned Formula (1), when absolute value of value is small, effect of thecorrection is weak, is too large conversely because effect of correction istoo strong, it is desirable to make range of - 0,00 1 to 0 ,001.

【００３０】図２は、本発明の光波長合分波器の一実施の形態であるアレイ導波路回折格子型光波長合分波器の所定部位における電界分布を模式的に示す説明図であり、図２（ａ）は、光信号のモード変換部１０３のＡ－Ａ'での電界分布１１３、図２（ｂ）は、アレイ導波路回折格子入射端１１４のＢ－Ｂ'での電界分布１１５、図２（ｃ）は、アレイ導波路回折格子出射端１１６のＣ－Ｃ'での電界分布１１７をそれぞれ示す。

[0030] As for Figure 2, it is a explanatory diagram which shows electric field distribution in specified site ofthe array waveguide diffraction grating type light wavelength divider/coupler which is a one embodiment of light wavelength divider/coupler of this invention in theschematic, as for Figure 2(a), electric field distribution 113 with A - A' of mode converting part 103 of the light signal, as for Figure 2(b), electric field distribution 115 with B - B' of array waveguide diffraction grating incident edge 114, as forthe Figure 2 (c), electric field distribution 117 with C - C' of array waveguide diffraction grating emitting end 116 is shownrespectively.

【００３１】図３は、本発明の光波長合分波器の一実施の形態であるアレイ導波路回折格子型光波長合分波器の所定部位における光信号の位相分布を模式的に示す説明図であり、図３（ａ）は、アレイ導波路回折格子入射端１１４のＢ－Ｂ'における光信号λ_1、λ_9の位相分布１１８、図３（ｂ）は、アレイ導波路回折格子出射端１１６における光信号λ_1、λ_9の位相分布１１９をそれぞれ示す。

[0031] As for Figure 3, it is a explanatory diagram which shows phase distribution of light signal inthe specified site of array waveguide diffraction grating type light wavelength divider/coupler which is a one embodiment of light wavelength divider/coupler of the this invention in schematic, as for Figure 3 (a), phase distribution 118 of light signal 1 and the 9 in B - B' of array waveguide diffraction grating incident edge 114, as for Figure 3 (b), phase distribution 119 of thelight signal 1 and 9 in

116 is shown respectively.

【００３２】図４は、本発明の光波長合分波器の一実施の形態であるアレイ導波路回折格子型光波長合分波器の所定部位における光信号の位相差を模式的に示す説明図であり、図４（ａ）は、光信号λ_1とλ_5との位相差１２０、図４（ｂ）、（ｃ）、（ｄ）は、光信号λ_3、λ_7、λ_9と、λ_5との位相差１２１，１２２，１２３をそれぞれ示す。

[0032] As for Figure 4, it is a explanatory diagram which shows phase shift of light signal inthe specified site of array waveguide diffraction grating type light wavelength divider/coupler which is a one embodiment of light wavelength divider/coupler of the this invention in schematic, as for Figure 4 (a), phase shift 120 of light signal 1 and the 5, as for Figure 4 (b), (c) and (d), phase shift 121,122,123 of light signal 3, 7 ,the 9 and 5 is shown respectively.

【００３３】図５は、本発明の光波長合分波器の一実施の形態であるアレイ導波路回折格子型光波長合分波器の集光面１２４における光信号λ_1、λ_3、λ_5、λ_7、λ_9の電界分布１２５，１２６，１２７，１２８，１２９をそれぞれ示す。ここで、アレイ導波路回折格子１０６の隣接チャネル導波路の導波路長差ΔＬは、前記式（３）を満足するように設計している。

[0033] As for Figure 5, electric field distribution 125,126,127,128,129 of light signal 1, 3, 5, the 7 and 9 in light collection surface 124 of array waveguide diffraction grating type light wavelength divider/couplerwhich is a one embodiment of light wavelength divider/coupler of this invention is shown respectively. Here, in order to satisfy aforementioned Formula (3), you design thewaveguide long difference L of adjacent channel waveguide of array waveguide diffraction grating 106.

【００３４】以下、図１を用い、かつ適宜他図を参照して、本発明の光波長合分波器の作用を説明する。

[0034] Below, making use of Figure 1, at same time referring to asneeded other figure, you explain action of light wavelength divider/coupler of this invention.

【００３５】光信号λ_1～λ_9は、入力導波路１０２、モード変換部１０３、入力スラブ導波路１０４、アレイ導波路回折格子１０６、出力スラブ導波路１０７、出力導波路１０８の順で伝搬する。まず、入力導波路１０２からアレイ導波路入射端１１４までの伝搬について説明する。

[0035] Light signal 1 to 9, input waveguide 102, mode c onverting part 103 and input slab waveguide 104, array waveguide diffraction grating 106and output slab waveguide 107, propagation does in order of output waveguide 108. First, you explain from input waveguide 102 concerning propagation to thearray waveguide incident edge 114.

【００３６】図１（ａ）に示すように、入射端１３０から入射された光信号λ_1～λ_9は、入力導波路１０２からモード変換部１０３へと伝搬する。光信号λ_1～λ_9はモード変換部１０３のＡ－Ａ′で、双峰状の電界分布１１３に変形される。

[0036] As shown in Figure 1 (a), from incident edge 130 light si gnal 1 to 9 which incidence isdone from input waveguide 102 propagation does to mode converting part 103. light signal 1 to 9 with A - A' of mode converting part 103, becomes deformed in electric field distribution 113of bimodal condition.

【００３７】図１（ｂ）に示すように、光信号λ_1～λ_9は入力スラブ導波路１０４において回折の効果により広げられ、図２（ｂ）に示すように、アレイ導波路回折格子入射端１１４のＢ－Ｂ′では、極大値、極小値をもつ分布１１５となる。

[0037] As shown in Figure 1 (b), light signal 1 to 9 is ex panded by effect of thediffraction in input slab waveguide 104, as shown in Figure 2(b), with B - B' of the array waveguide diffraction grating incident edge 114, becomes distribution 115 which has maximum value and the extremely small value.

【００３８】図３（ａ）に示すように、位相分布１１８は、モード変換部１０３において電界分布を双峰状にしたことにより、一部にπだけずれた分布１２９を持つ形状となる。

[0038] As shown in Figure 3 (a), phase distribution 118 is in part by designatingthe electric field distribution as bimodal condition in mode converting part 103, and it becomes geometrywhich has distribution 129 which can be shaved.

【００３９】次に、アレイ導波路回折格子１０６から出力導波路１０８までの光信号の様子について説明する。なお、この部分では光信号の波長によって伝搬の様子が異なるため、まず前記式（３）を満足するλ_5について説明し、次にその他の光信号について説明する。

[0039] Next, you explain concerning circumstances of light sig nal to theoutput waveguide 108 from array waveguide diffraction grating 106. Furthermore , because with this portion circumstances of thepropagation differ depending upon wavelength of light signal, you explainconcerning 5 which first satisfies aforementioned Formula (3),next you explain concerning other light signal.

【００４０】図１（ｂ）に示すように、光信号λ_5はアレイ導波路回折格子入射端１１４のＢ－Ｂ′において、各チャネル導波路１０６に入射・分割され、それぞれのチャネル導波路内を伝搬する。アレイ導波路回折格子終端１１６のＣ－Ｃ′では再び一つに収束する。

[0040] As shown in Figure 1 (b), light signal 5 incident * is d ivided by eachchannel waveguide 106 in B - B' of array waveguide diffraction grating incident edge 114, propagation does inside respectivechannel waveguide. With C - C' of array waveguide diffraction grating terminal 116 it focuses again in one.

【００４１】図２（ｃ）に示すように、電界分布１１７は、入射端１１４のＢ－Ｂ′での電界分布１１５とほぼ同じ形状となる。図３（ｂ）に示す位相分布１１９については、光信号λ_5が前記式（３）を満足するため、アレイ導波路回折格子伝搬前と全く同じように左右対称で一部にπだけ位相のずれた分布になる。したがって、図１（ｂ）に示すように、光信号λ_5は出力スラブ導波路１０７上の基準点１１０に焦点を結ぶ。

[0041] As shown in Figure 2 (c), electric field distribution 117 e lectric field distribution 115 with B - B' of incident edge 114and almost becomes same shape. Because light signal 5 satisfies aforementioned Formula (3) concerning thephase distribution 119 which is shown in Figure 3 (b), completely in same way asbefore array waveguide diffraction grating propagation with left-right symmetry in part just it becomes thedistribution to which phase slips. Therefore, as shown in

【００４２】図５に示すように、その電界分布１２７は、図２（ａ）に示すモード変換部１０３での電界分布１１３とほぼ同形状となる。さらに、図１（ｂ）に示すように、光信号λ_5は基準点１１０に接続された出力導波路を伝搬し、出力端から出射される。

【００４３】以下、λ_5以外の光信号について説明する。ここでは、例として光信号λ_1、λ_3、λ_7、λ_9の場合ついて説明する。図１に示すように、光信号λ_1、λ_3、λ_7、λ_9もそれぞれアレイ導波路回折格子１０６で分割され、それぞれチャネル導波路１０５を伝搬する。アレイ導波路回折格子１０６伝搬後の電界分布は、光信号λ_5の場合とほぼ同じである。

【００４４】ただし、図４（ａ）、（ｂ）、（ｃ）、（ｄ）に示すように、位相分布については、曲線状で、かつ全体的に傾斜している、曲線の度合い及び傾きは光信号λ_5との波長の差が大きくなるほど大きくなっている。位相差が全体的に傾斜しているのは、伝搬定数βが波長分散を持つためであり、この傾きによって集光位置が異なっている。位相差が曲線状になるのはアレイ導波路回折格子１０６を構成するチャネル導波路１０５の間隔が前記式（４）に示したように全体的に変化しているためであり、出力スラブ導波路等における収差を相殺する効果を持つ。

【００４５】したがって、各光信号は、出力スラブ導波路１０７の集光面１２４のＤ－Ｄ'上の点X_1～X_9（図示せず）にそれぞれ集光し、その電界分布１２５，１２６，１２８，１２９も収差が相殺され、各光信号とも左右対称の双峰状となる。さらに、各信号は各出力導波路１０８に入射、伝搬し、出力端１３１から別々に取り出すことができる。

【００４６】図６は、本発明の光波長合分波器の一実施の形態であるアレイ導波路回折格子型光波長合分波器の損失波長特性１３２を模式的に示す説明図である。

【００４７】図５及び図６に示すように、各出力導波路１０８の挿入損失は、集光面１２４のＣ－Ｃ'における光信号の電界分布１２５，１２６，１２７，１２８，１２９と、各出力導波路１０８の固有モードの重畳積分で

Figure 1 (b), light signal 5 ties focus to thereference point 110 on output slab waveguide 107.

[0042] As shown in Figure 5, electric field distribution 127 electric field distribution 113 with mode converting part 103 which isshown in Figure 2(a) and almost becomes same geometry. Furthermore, as shown in Figure 1 (b), light signal 5 propagation does theoutput waveguide which is connected to reference point 110, radiation is done fromthe output terminal.

[0043] You explain concerning light signal below and other than 5. Here, as example in case of light signal 1, 3, 7 and the 9 being attached, you explain. As shown in Figure 1, also light signal 1, 3, 7 and the 9 are divided respectively with array waveguide diffraction grating 106, propagation do therespective channel waveguide 105. electric field distribution after array waveguide diffraction grating 106 propagation is almost same as case of light signal 5.

[0044] However, as Figure 4 (a), (b), (c), shown in (d), with curve shape, at thesame time it is inclined to entire concerning phase distribution, extent and slope of curve extent where difference of wavelength ofthe light signal 5 becomes large have become large. Fact that phase shift is inclined to entire, is, because the propagation constant has wavelength dispersion, light collection position differs depending upon this slope. Fact that phase shift becomes curve shape as spacing of channel waveguide 105which forms array waveguide diffraction grating 106 shows in aforementioned Formula (4), is, becauseit has changed in entire, has effect which offsets aberration inthe output slab waveguide etc.

[0045] Therefore, each light signal light collection makes respectively point X 1 to X9 (not shown) on theD - D' of light collection surface 124 of output slab waveguide 107, aberration isoffset also electric field distribution 125,126,128,129, also each light signal becomes bimodal condition of theleft-right symmetry. Furthermore, each signal incidence and propagation does in each outputwaveguide 108, it is possible to remove from output terminal 1 31 separately.

[0046] Figure 6 is explanatory diagram which shows loss wavelength characteristic 132 of array waveguide diffraction grating typelight wavelength divider/coupler which is a one embodiment of light wavelength divider/coupler of this invention in schematic.

[0047] Way it shows in Figure 5 and Figure 6, as for insertion loss of each output waveguide 108, itis decided with electric field distribution 125,126,127,128,129 of light signal in C - C' of light collectionsurface 124 and superimposition integral calculus

決定される。光信号の電界分布１２５、１２６、１２７、１２８、１２９が、波長に応じて集光面１２４のＤ－Ｄ'上を、双峰状の形状を保ったまま移動する。そのため、光信号の波長がわずかに変動しても、挿入損失はあまり変化しない。つまり、図６に示すように損失波長特性１３２は、各光信号の波長λ_1～λ_9に通過帯域１３３内の波長変動が生じても通過帯域１３３が平坦かつ左右対称であるため、挿入損失は増加しない。

of peculiar mode of each outputwaveguide 108. electric field distribution 125,126,127,128,129 of light signal, on D - D' of light collection surface 124, whilethe geometry of bimodal condition is maintained moves according to the wavelength. Because of that, wavelength of light signal fluctuating barely, insertion lossdoes not change excessively. In other words, as shown in Figure 6, as for loss wavelength characteristic 132, wavelengthfluctuation inside passing domain 133 occurring in wavelength 1 to 9 of eachlight signal, because passing domain 133 is flat and left-right symmetry, as forthe insertion loss it does not increase.

【００４８】なお、本発明の光波長合分波器に用いられる基板としては、例えば、ガラス基板だけでなく半導体基板等にも形成することができる。また、基板１０１上に形成されるコア、クラッド、バッファ層についても、ガラス系の材料だけでなく半導体材料など、光学的に透明な材料を用いて形成することも可能である。

[0048] Furthermore, it can form even in semiconductor substrat e etc not only a for example glass substrate as thesubstrate which is used for light wavelength divider/coupler of this invention. In addition, concerning core, cladding and buffer layer which areformed on substrate 101, not only a material of glass type forming making useof, optically transparent material such as semiconductor material it is possible.

【００４９】

【発明の効果】以上説明した通り、本発明の光波長合分波器によると、入力スラブ導波路及び出力スラブ導波路におけるアレイ導波路回折格子の各チャネル導波路の配置角度を最適化することで、出力スラブ導波路における収差等を相殺し、全出力導波路において、平坦な通過域特性を実現できるので、光源の波長変動に対する損失変動が小さく、かつ安定した光信号の合分波が可能な光波長合分波器を提供することができる。

[0049]

[Effects of the Invention] Above you explained sort, According to light wavelength divider/coupler of this invention, Input slab waveguide and positioning angle of each channel waveguide of array waveguide diffraction grating in outputslab waveguide optimization do with, To offset aberration etc in output slab waveguide, because planar passinglimits characteristic can be actualized in full power waveguide, light wavelength divider/couplerwhere combination amount wave of light signal to which lossfluctuation for wavelength fluctuation of light source is small, at thesame time stabilizes is possible can be offered.

【００５０】

[0050]

【図面の簡単な説明】

[Brief Explanation of the Drawing(s)]

【図１】本発明の光波長合分波器の一実施の形態であるアレイ導波路回折格子型光波長合分波器を模式的に示す説明図であり、図１（ａ）は、その全体図で、図１（ｂ）は、アレイ導波路回折格子部の拡大図である。

[Figure 1] It is a explanatory diagram which shows array waveguide diffraction grating type light wavelength divider/coupler which is a one embodiment of thelight wavelength divider/coupler of this invention in schematic as for Figure 1 (a), with whole diagram, asfor Figure 1 (b), is a expanded view of array waveguide diffraction grating section.

【図２】本発明の光波長合分波器の一実施の形態であるアレイ導波路回折格子型光波長合分波器の所定部位における電界分布を模式的に示す説明図であり、図２（ａ）は、光信号のモード変換部１０３のＡ－Ａ'での電界分布１１３、図２（ｂ）は、アレイ導波路回折格子入射端１１４のＢ－Ｂ'での電界分布１１５、図２（ｃ）は、アレイ導波路回折格子出射端１１６のＣ－Ｃ'での電界分布１１７をそれぞれ示す。

[Figure 2] It is a explanatory diagram which shows electric field distribution in specified site of array waveguide diffraction grating typelight wavelength divider/coupler which is a one embodiment of light wavelength divider/coupler of this invention in schematic, as forthe Figure 2(a), electric field distribution 113 with A - A' of mode converting part 103 of light signal, as forthe Figure 2(b), electric field distribution 115 with B - B' of array waveguide diffraction grating incident edge

114, as for Figure 2 (c),the electric field distribution 117 with C - C' of array waveguide diffraction grating emitting end 116 is shown respectively.

【図３】本発明の光波長合分波器の一実施の形態であるアレイ導波路回折格子型光波長合分波器の所定部位における光信号の位相分布を模式的に示す説明図であり、図３（ａ）は、アレイ導波路回折格子入射端１１４のＢ－Ｂ'における光信号λ_1、λ_5の位相分布１１８、図３（ｂ）は、アレイ導波路回折格子出射端１１６における光信号λ_1、λ_9の位相分布１１９をそれぞれ示す。

[Figure 3] It is a explanatory diagram which shows phase distribution of light signal in specified site of thearray waveguide diffraction grating type light wavelength divider/coupler which is a one embodiment of light wavelength divider/coupler of this invention in theschematic, as for Figure 3 (a), phase distribution 118 of light signal 1 and 9 in theB - B' of array waveguide diffraction grating incident edge 114, as for Figure 3 (b), phase distribution 119 of light signal 1 and the 9 in array waveguide diffraction grating emitting end 116 is shown respectively.

【図４】本発明の光波長合分波器の一実施の形態であるアレイ導波路回折格子型光波長合分波器の所定部位における光信号の位相差を模式的に示す説明図であり、図４（ａ）は、光信号λ_1とλ_5との位相差１２０、図４（ｂ）、（ｃ）、（ｄ）は、光信号λ_3、λ_7、λ_9と、λ_5との位相差１２１、１２２、１２３をそれぞれ示す。

[Figure 4] It is a explanatory diagram which shows phase shift of light signal in specified site of thearray waveguide diffraction grating type light wavelength divider/coupler which is a one embodiment of light wavelength divider/coupler of this invention in theschematic, as for Figure 4 (a), phase shift 120 of light signal 1 and 5, as forthe Figure 4 (b), (c) and (d), phase shift 121,122,123 of light signal 3, 7, 9 andthe 5 is shown respectively.

【図５】本発明の光波長合分波器の一実施の形態であるアレイ導波路回折格子型光波長合分波器の集光面１２４における光信号λ_1、λ_3、λ_5、λ_7、λ_9の電界分布１２５、１２６、１２７、１２８、１２９をそれぞれ示す。

[Figure 5] Electric field distribution 125,126,127,128,129 of light signal 1, 3, 5, 7 and 9 in light collection surface 124 of array waveguide diffraction grating type light wavelength divider/coupler which is a one embodiment ofthe light wavelength divider/coupler of this invention is shown respectively.

【図６】本発明の光波長合分波器の一実施の形態であるアレイ導波路回折格子型光波長合分波器の損失波長特性１３２を模式的に示す説明図である。

[Figure 6] It is a explanatory diagram which shows loss wavelength characteristic 132 of array waveguide diffraction grating type light wavelength divider/coupler whichis a one embodiment of light wavelength divider/coupler of this invention in schematic.

【図７】従来のアレイ導波路回折格子型光波長合分波器を模式的に示す説明図である。

[Figure 7] It is a explanatory diagram which shows conventional array waveguide diffraction grating type light wavelength divider coupler in schematic.

【図８】従来のアレイ導波路回折格子型光波長合分波器の所定部位における光信号の電界分布を模式的に示す説明図であり、図８（ａ）は、モード変換部２０３のＥ－Ｅ'における光信号の電界分布２０９、図８（ｂ）は、アレイ導波路回折格子入射端２１０のＦ－Ｆ'における電界分布２１１、図８（ｃ）は、アレイ導波路回折格子出射端２１２のＧ－Ｇ'での電界分布２１３をそれぞれ示す。

[Figure 8] It is a explanatory diagram which shows electric field distribution of light signal in specified site of theconventional array waveguide diffraction grating type light wavelength divider coupler in schematic, as for Figure 8 (a), electric field distribution 209 of thelight signal in E - E' of mode converting part 203, as for Figure 8 (b), electric field distribution 211 and the Figure 8 (c) in F - F' of array waveguide diffraction grating incident edge 210 show electric field distribution 213 with G - G' of the array waveguide diffraction grating emitting end 212 respectively.

【図９】従来のアレイ導波路回折格子型光波長合分波器

[Figure 9] It is a explanatory diagram which shows phase distribu

の所定部位における光信号の位相分布を模式的に示す説明図であり、図９（ａ）、図９（ｅ）、図９（ｆ）は、アレイ導波路回折格子出射端２１２のＧ－Ｇ’での光信号λ_1、λ_5、λ_9のそれぞれの位相分布２１４、２１５、２１６を示す。

tion of light signal in specified site of theconventional array waveguide diffraction grating type light wavelength divider/coupler in schematic, Figure 9 (a), Figure 9 (e) and Figure 9 (f), thelight signal 1 with G - G' of array waveguide diffraction grating emitting end 212, show respective phase distribution 214,215,216 of the 5 and 9.

【図１０】従来のアレイ導波路回折格子型光波長合分波器の所定部位における光信号の位相分布の差を模式的に示す説明図であり、図１０（ａ）及び図１０（ｂ）は、光信号λ_1、λ_9の位相面２１４、２１６とλ_5の位相面２１５とのそれぞれの位相分布の差２１７、２１８を示す。

[Figure 10] It is a explanatory diagram which shows difference of phase distribution of light signal inthe specified site of conventional array waveguide diffraction grating type light wavelength divider/coupler in schematic, Figure 10 (a) and theFigure 10 (b), show difference 217,218 of respective phase distribution of phasesurface 214,216 of light signal 1 and 9 and phase surface 215of 5.

【図１１】従来のアレイ導波路回折格子型光波長合分波器の集光面２１９のＨ－Ｈ’における光信号λ_1、λ_5、λ_9の電界分布２２０、２２１、２２２を模式的に示す説明図である。

[Figure 11] It is a explanatory diagram which shows electric field distribution 220,221,222 of light signal 1, 5 and the 9 in H - H' of light collection surface 219 of conventional array waveguide diffraction grating type light wavelength divider/couplerin schematic.

【図１２】従来のアレイ導波路回折格子型光波長合分波器の損失波長特性２２４、２２５、２２６、２２７を模式的に示す説明図である。

[Figure 12] It is a explanatory diagram which shows loss wavelength characteristic 22 4, 2 25,226,227 of conventional array waveguide diffraction grating type light wavelength divider/coupler inthe schematic.

【符号の説明】

[Explanation of Reference Signs in Drawings]

１０１：基板

101: Substrate

１０２：入力用導波路

102: Waveguide for input

１０３：モード変換部

103 : Mode converting part

１０４：入力スラブ導波路

104: Input slab waveguide

１０５：チャネル導波路

105: Channel waveguide

１０６：アレイ導波路回折格子

106: Array waveguide diffraction grating

１０７：出力側スラブ導波路

107: Output side slab waveguide

１０８：出力用導波路

108: Waveguide for output

１０９：基準点

109: Reference point

１１０：基準点

110 : Reference point

１１１：第ｉチャネル導波路が第ｉ＋１チャネル導波路となす角度

111: I'th channel waveguide forms i'th + 1 channel waveguide angle

１１２：所定の第ｊチャネル導波路が第ｊ＋１チャネル導波路となす角度

112: Specified j channel waveguide forms j + 1 channel waveguide angle

１１３：モード変換部における光信号の電界分布

113: In mode converting part electric field distribution of light s ignal

１１４：アレイ導波路回折格子入射端

114: Array waveguide diffraction grating incident edge

１１５：アレイ導波路回折格子入射端における光信号の電界分布

115: In array waveguide diffraction grating incident edge electric field distribution of light signal

１１６：アレイ導波路回折格子出射端

116: Array waveguide diffraction grating emitting end

１１７：アレイ導波路回折格子出射端における光信号の電界分布

117: In array waveguide diffraction grating emitting end electric field distribution of light signal

１１８：アレイ導波路回折格子入射端における光信号λ_1〜λ_9の位相分布

118: In array waveguide diffraction grating incident edge phase distribution of light signal 1 to 9

１１９：アレイ導波路回折格子出射端における光信号λ_5の位相分布

119: In array waveguide diffraction grating emitting end phase d istribution of light signal 5

１２０：アレイ導波路回折格子出射端における光信号λ_1の位相分布と光信号λ_5の位相分布との差

120: Difference of phase distribution of light signal 1 in arra y waveguide diffraction grating emitting end and phase distribution of thelight signal 5

１２１：アレイ導波路回折格子出射端における光信号λ_3の位相分布と光信号λ_5の位相分布との差

121: Difference of phase distribution of light signal 3 in arra y waveguide diffraction grating emitting end and phase distribution of thelight signal 5

１２２：アレイ導波路回折格子出射端における光信号λ_7の位相分布と光信号λ_5の位相分布との差

122: Difference of phase distribution of light signal 7 in arra y waveguide diffraction grating emitting end and phase distribution of thelight signal 5

１２３：アレイ導波路回折格子出射端における光信号λ_9の位相分布と光信号λ_5の位相分布との差

123: Difference of phase distribution of light signal 9 in arra y waveguide diffraction grating emitting end and phase distribution of thelight signal 5

１２４：集光面

124: Light collection surface

１２５：集光面における光信号λ_1の電界分布

125: In light collection aspect electric field distribution of light s ignal 1

１２６：集光面における光信号λ_3の電界分布

126: In light collection aspect electric field distribution of light s ignal 3

１２７：集光面における光信号λ_5の電界分布

127: In light collection aspect electric field distribution of light s ignal 5

１２８：集光面における光信号λ_7の電界分布

128: In light collection aspect electric field distribution of light s ignal 7

１２９：集光面における光信号λ_9の電界分布

129: In light collection aspect electric field distribution of light s ignal 9

１３０：光信号λ_5の焦点位置

130: Focal position of light signal 5

１３１：焦点位置

131 : Focal position

１３２：出力端

132: Output terminal

１３３：通過域

133: Passing limits

２０１：基板

201: Substrate

２０２：入力用導波路	202: Waveguide for input
２０３：モード変換部	203: Mode converting part
２０４：入力スラブ導波路	204: Input slab waveguide
２０５：チャネル導波路	205: Channel waveguide
２０６：アレイ導波路回折格子	206: Array waveguide diffraction grating
２０７：出力側スラブ導波路	207: Output side slab waveguide
２０８：出力用導波路	208: Waveguide for output
２０９：ード変換部における光信号の電界分布	209: In - F converting part electric field distribution of light s ignal
２１０：アレイ導波路回折格子入射端	210: Array waveguide diffraction grating incident edge
２１１：アレイ導波路回折格子入射端における光信号の電界分布	211: In array waveguide diffraction grating incident edge electric field distribution of light signal
２１２：アレイ導波路回折格子出射端	212: Array waveguide diffraction grating emitting end
２１３：レイ導波路回折格子出射端における光信号の電界分布	213: In ray waveguide diffraction grating emitting end げる elect ric field distribution of light signal
２１４：アレイ導波路回折格子出射端における光信号λ_1の位相分布	214: In array waveguide diffraction grating emitting end phase d istribution of light signal 1
２１５：アレイ導波路回折格子出射端における光信号λ_5の位相分布	215: In array waveguide diffraction grating emitting end phase d istribution of light signal 5
２１６：アレイ導波路回折格子出射端における光信号λ_9の位相分布	216: In array waveguide diffraction grating emitting end phase d istribution of light signal 9
２１７：アレイ導波路回折格子出射端における光信号λ_1の位相分布と光信号λ_5の位相分布との差	217: Difference of phase distribution of light signal 1 in arra y waveguide diffraction grating emitting end and phase distribution of the light signal 5
２１８：アレイ導波路回折格子出射端における光信号λ_9の位相分布と光信号λ_5の位相分布との差	218: Difference of phase distribution of light signal 9 in arra y waveguide diffraction grating emitting end and phase distribution of the light signal 5
２１９：集光面	219: Light collection surface
２２０：集光面における光信号λ_1の電界分布	220: In light collection aspect electric field distribution of light s ignal 1
２２１：集光面における光信号λ_5の電界分布	221: In light collection aspect electric field distribution of light s ignal 5
２２２：集光面における光信号λ_9の電界分布	222: In light collection aspect electric field distribution of light s ignal 9
２２３：出力端	223: Output terminal
２２４：第５出力導波路の損失波長特性	224: Loss wavelength characteristic of 5th output waveguide

２２５：第１出力導波路の損失波長特性

225: Loss wavelength characteristic of 1st output waveguide

２２６：第９出力導波路の損失波長特性

226: Loss wavelength characteristic of 9th output waveguide

２２７：通過帯域

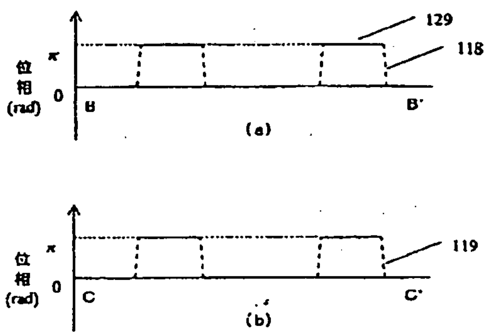
227: Passing domain

２２８：第５出力導波路

228: 5th output waveguide

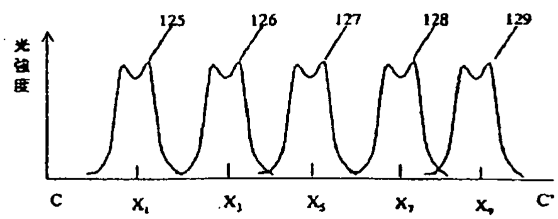
【図３】

[Figure 3]



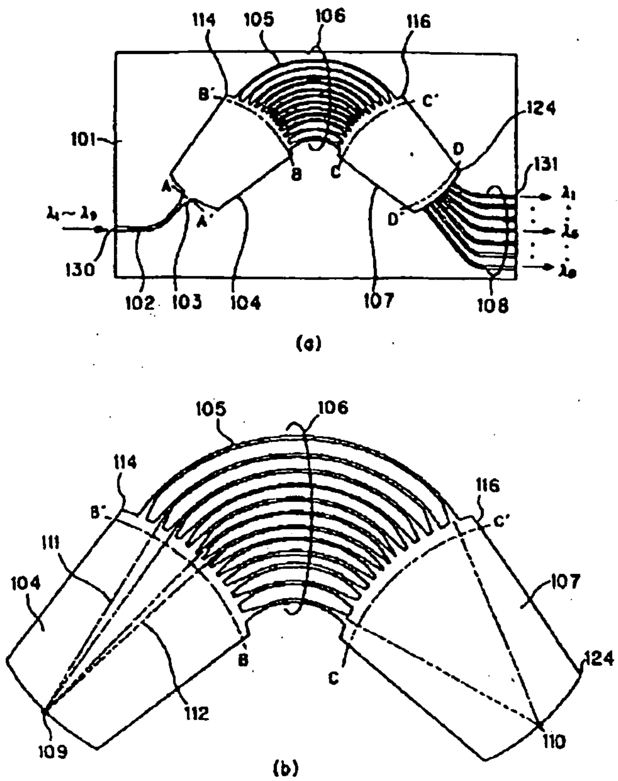
【図５】

[Figure 5]



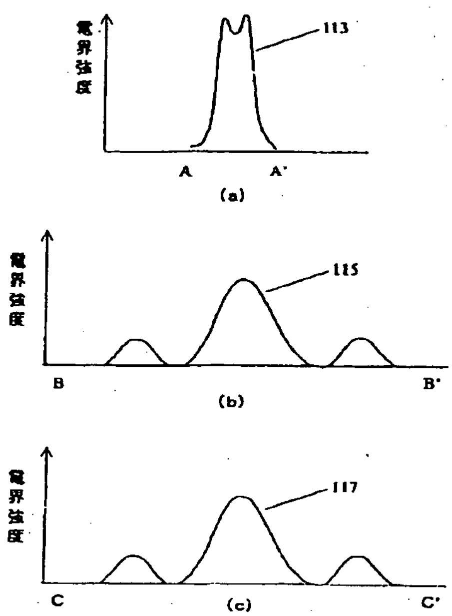
【図1】

[Figure 1]



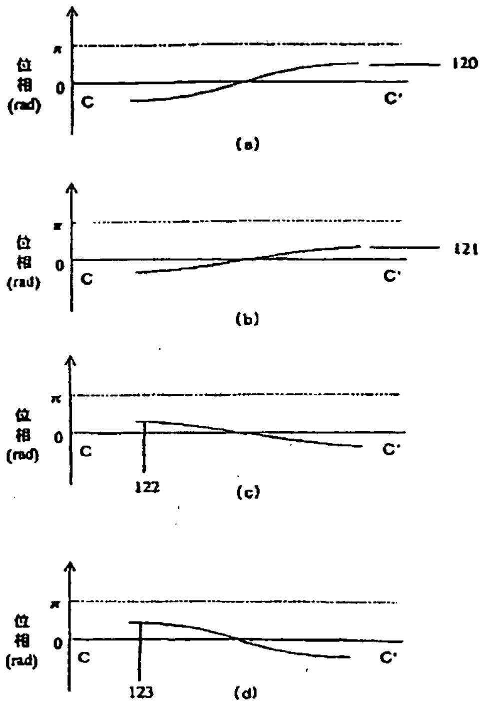
【図2】

[Figure 2]



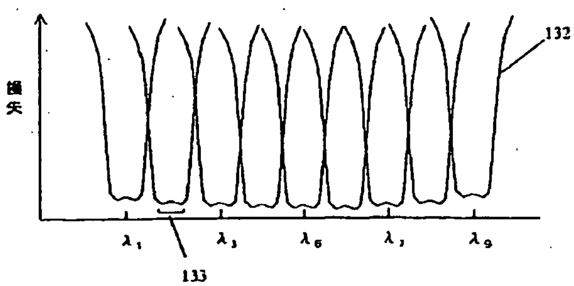
【図4】

[Figure 4]



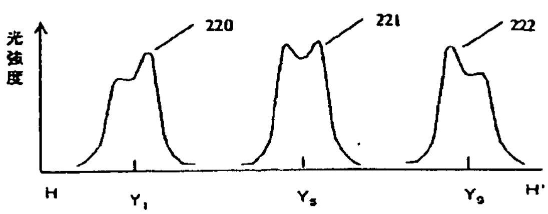
【図6】

[Figure 6]



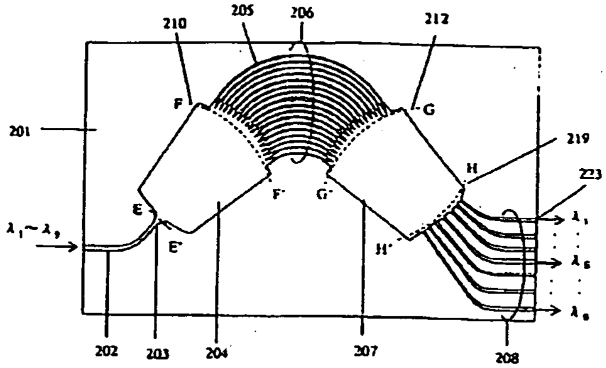
【図11】

[Figure 11]



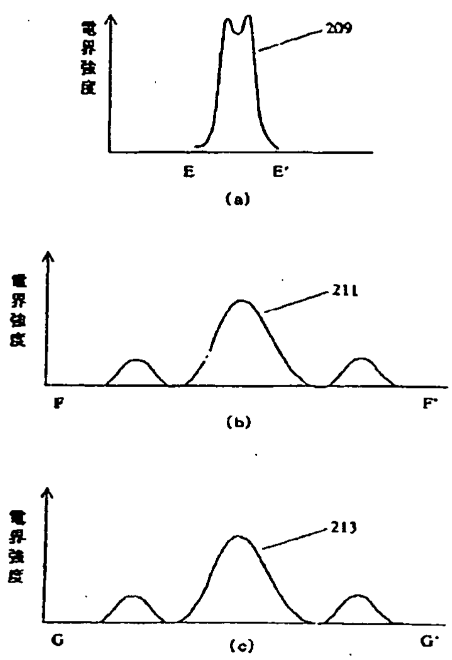
【図7】

[Figure 7]



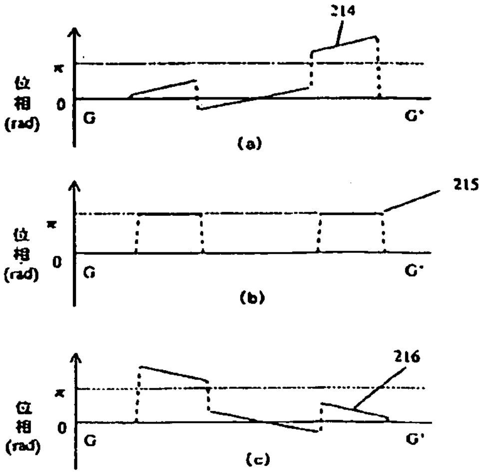
【図8】

[Figure 8]



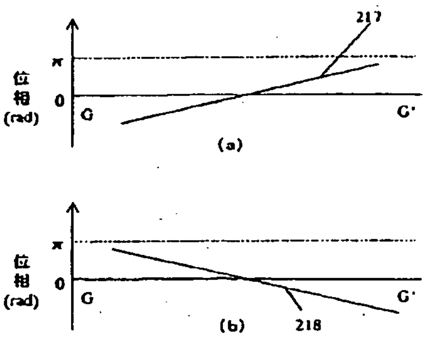
【図9】

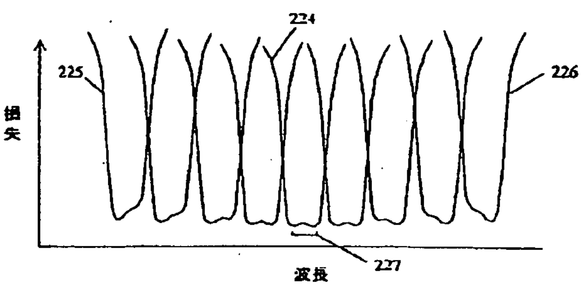
[Figure 9]



【図10】

[Figure 10]





【図12】

[Figure 12]

JAPANESE PATENT OFFICE

Patent Application Laid Open

Japanese Patent Kokai 2001-13336 (P2001-13336A)

Date of Publication: 19 January 2001

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Request for Examination: Not Requested

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6/293		6/28	D	

Title of the Invention: An Optical Wavelength Multiplexer/Branching Filter

Application No.: Hei 11-180118

Date of Aplication: 25 June 1999

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F terms (reference) 2H047, KA02, KA03, LA01, LA19, LA23.

Abstrract (There is an amendment)

Problem To provide an optical wavelength multiplexer/branching filter where there is little loss fluctuation for fluctuations in the wavelength of the light source and stable combination/dividing of optical signals is possible.

Means of Solution It is provided with array waveguide diffraction grating 106 and fan-shaped input side slab waveguide 104, which connects the said input channel waveguide 102 and array waveguide diffraction grating 106, and fan-shaped output side slab waveguide 107, which connects the said output channel waveguides 108 and the said array waveguide diffraction grating 106; in at least 1 out of the connecting section for the said input side slab waveguide 104 and the said array waveguide diffraction grating 106 or the connecting section for the said output side slab waveguide 107 and the said array waveguide diffraction grating 106, the spacing between the central axis of each of the channel waveguides 105, which form array waveguide grating 106, and the central axes of the respective adjacent channel waveguides 105 gradually varies across all the channel waveguides 105.

Scope of Patent Claims

Claim 1 An optical wavelength multiplexer/branching filter characterised in that

it is an optical wavelength multiplexer/branching filter which is provided, on a substrate, with 1 or more input channel waveguides and 1 or more output channel waveguides and an array waveguide diffraction grating consisting of a plurality of channel waveguides, in which the waveguide length is sequentially made longer by the requisite length from the shortest to the longest, and a fan-shaped input side slab waveguide, which connects the said input channel waveguide and the array waveguide diffraction grating, and a fan-shaped output side slab waveguide, which connects the said output channel waveguide and the said array waveguide diffraction grating;

and in at least 1 out of the conecting section for the said input slab waveguide and the said array waveguide diffraction grating or the connecting section for the said output side waveguide and the said array waveguide diffraction grating the space between the central axis of each of the channel waveguides, which form the said array waveguide grating, and the central axes of the respective adjacent channel waveguides gradually varies across all the channel waveguides.

Claim 2 The optical wavelength multiplexer/branching filter disclosed in Claim 1 where, in the said connecting section for the said input side slab waveguide and the said connecting section for the said output side slab waveguide, the said channel waveguides that form the said array waveguide diffraction grating are respectively arranged in a radiating shape along the said input side slab waveguide and the said output side slab waveguide; and the angle with respect to the prescribed datum point between the central axis of each of the said channel waveguides and the central axes of the respective adjacent channel waveguides gradually varies across all the channel waveguides.

Claim 3 The optical wavelength multiplexer/branching filter disclosed in Claim 2 where, if the number of the said channel waveguides forming the said array waveguide diffraction grating is made N, the waveguide number of each of the said channels is made i and the channel waveguide number of the datum established beforehand is made j, the angle $\Delta\theta i$ with respect to the said prescribed datum point between the channel waveguide that is number i and the one that is i + 1 in the said connecting section of the said input side slab waveguide or the said output side slab waveguide is gradually varied, as shown in equation (1) below.

$$\Delta\theta i = \Delta\theta j.\{1 + \Sigma A_k. |i - j| k\} \ldots\ldots\ldots\ldots\ldots (1)$$

(In equation (1), A_k is a constant and k is an integer from 1~N.)

Claim 4 The optical wavelength multiplexer/branching filter disclosed in Claim 3 where, in the said equation (1), the range of the pescribed constant A is made to be $-0.001 \leq A_k \leq 0.001$ (k is an integer from 1~N).

Claim 5 The optical wavelength multiplexer/branching filter disclosed in Claims 3 or 4 where, in the said equation (1), by making the number (N) of channel waveguides forming the said array waveguide diffraction grating to be 1, the said angle $\Delta\theta i$ is made to be the one shown in equation (2) below.

$$\Delta\theta i = \Delta\theta j.\{1 + A_1. |i - j|\} \ldots\ldots\ldots\ldots\ldots (2)$$

(In equation (2), A_1 is a constant and A_1 does not equal 0.)

Detailed Explanation of the Invention

0001

Technical Field to which the Invention Belongs

The present invention relates to an optical wavelength multiplexer/branching filter. In particular, it relates to an optical wavelength multiplexer/branching filter where loss fluctuation for fluctuations in wavelength of the light source are small and stable combining/dividing of optical signals is possible.

0002

Prior Art

The array waveguide diffraction grating is regarded as promising as an optical wavelength multiplexer/branching filter which combines or divides a plurality of optical signals with different wavelengths. Various ones have been proposed (Japanese Patent Publications Hei 4-116607, 4-1634064, 4-220624, 4-326308, 5-157920). In particular, as there is little insertion loss fluctuation for fluctuations in the wavelength of the light source and stable multiplexing and branching of optical signals is possible with an array waveguide diffraction grating type of optical wavelength multiplexer/branching filter where the passing band characteristics have been flattened out, this is looked forward to as a useful device in optical wavelength multiple signals (US Patent 5412744).

0003 Fig.7 is an explanatory diagram showing typically a conventional array waveguide diffraction grating type of optical wavelength multiplexer/branching filter. Here, as an example, an optical wavelength multiplexer/branching filter is shown for multiplexing and separating the 9 optical signals λ_1 ~ λ_9 ($\lambda_1 < \lambda_2 < ......\lambda_8 < \lambda_9$). As show in Fig.7, the conventional optical wavelength multiplexer/branching filter is made up, on a substrate, of input waveguide 202, input side slab waveguide 204, array waveguide diffraction grating 206, which consists of a plurality of channel waveguides 205 with the length of each differing by ΔL, explained later, output slab waveguide 207 and 9 output waveguides 208. Furthermore, mode conversion section 203 has been formed in the connecting section of input waveguide 202 with input slab waveguide 204 in order to level out the pass band characteristics of loss wavelength characteristics.

0004 Fig.8 is an explanatory diagram showing typically the electrical field distribution of the optical signals in a specific region of a conventional array waveguide diffraction grating type of optical wavelength multiplexer/branching filter. Fig.8(a) shows electrical field distribution 209 of the optical signal at E-E' of mode conversion section 203. Fig.8(b) shows the electrical field distribution at F-F' of array waveguide diffraction grating input terminal 210. Fig.8(c) shows the electrical field distribution 213 at G-G' of array waveguide diffraction grating emitting end 212.

0005 Fig.9 is an explanatory diagram showing typically the phase distribution of the optical signals in a specific region of a conventional array waveguide diffraction grating type of optical wavelength multiplexer/branching filter. Fig.9(a), 9(e) *[sic – translator]* and 9(f) *[sic – translator]* show respectively phase distributions 214, 215 and 216 of optical signals λ_1, λ_5 and λ_9 at G-G' of array waveguide diffraction grating emitting end 212.

0006 Fig.10 is an explanatory diagram showing typically the difference in phase distribution of the optical signals in a specific region of a conventional array waveguide diffraction grating type of optical wavelength multiplexer/branching filter. Fig.10(a) and 10(b) show the respective phase distribution differences 217 and 218 between phase planes 214 and 216 of optical signals λ_1 and λ_9 and phase plane 215 of λ_5.

0007 Fig.11 is an explanatory diagram showing typically electrical field distributions 220, 221 and 222 of optical signals λ_1, λ_5 and λ_9 at H-H' of condensing surface 219 of a conventional array waveguide diffraction grating type of optical wavelength multiplexer/branching filter.

0008 An explanation will be given below of the action of a conventional optical wavelength multiplexer/branching filter using Fig.7 and making reference to other appropriate diagrams. The

waveguide length difference ΔL between adjacent channel waveguides 205 forming array waveguide diffraction grating 206 has been designed by equation 3 below.

$$\Delta L = 2.m.\pi/\beta(\lambda_5)\text{.........}(3)$$

(In equation (3), m denotes diffraction degree (a positive integer). $\beta(\lambda_5)$ denotes the channel waveguide propagation constant for optical signal λ_5.)

0009 Optical signals $\lambda_1 \sim \lambda_9$, which are incident from input waveguide 202, are propagated in the order mode conversion section 203, input slab waveguide 204, array waveguide diffraction grating 205, output slab waveguide 207 and output waveguide 208.

0010 As shown in Fig.8(a), the electrical field distribution 209 of the optical signal at E-E' of mode conversion section 203 is a twin peaked shape, symmetrical to left and right.

0011 As shown in Fig.8(b), the electrical field distribution 211 at F-F' at the array waveguide diffraction grating 206 incident end 210 of input slab waveguide 204 is a distribution that has maximum and minimum values as an effect of diffraction. At F-F' at the array waveguide diffraction grating incident end 210 the optical signal is divided and is incident and propagated along each channel waveguide 206.

0012 As shown in Fig.8(c), electrical field distribution 213 at G-G' at end 212 of array waveguide diffraction grating 205 *[sic – translator]* reproduces the electrical field distribution at F-F' of incident end 210 for all the signals.

0013 As shown in Fig.9(a), (b) and (c), phase plane 214 of optical signals $\lambda_1 \sim \lambda_9$ at G-G' of end 212 differs according to the optical signal. Here, from equation (3) above, phase plane 215 of optical signal λ_5 becomes symmetrical to right and left. The phase planes of the other optical signals produce a slope with respect to H-H' at array waveguide diffraction grating end 219 according to the propagation constant.

0014 As shown in Fig.10, the phase difference changes continuously in channel waveguides 205 of array waveguide diffraction grating 206. Each optical signal is propagated in a direction corresponding to the slope at output slab waveguide 207. Consequently, the various optical signals respectively condense at different points $Y_1 \sim Y_9$ (not shown in the diagram) of condensing surface 219 of output slab waveguide 207.

0015 Here, as shown in Fig.11, the electrical field distributions 220, 221 and 222 of the respective signals at H-H' of condensing surface 219 are affected by aberrations and suchlike in output slab waveguide 207. Although electrical field distribution 221 of optical signal λ_5 reproduces electrical field

distribution 209 of mode conversion section 203 and becomes a twin peak shape that is symmetrical to right and left, electrical field distributions 220 and 221 of signals λ_1, and λ_9 become asymmetrical to right and left. As the asymmetry is mainly caused by aberrations in output slab waveguide 207, the further the optical signal condenses towards the edge of H-H' of condensing surface 219 the bigger the asymmetry becomes. The various signals at H-H' of condensing surface 219 are incident upon the various output waveguides 208, are propagated and can be extracted separately from output end 223.

0016 Fig.12 is an explanatory diagram showing typically the loss wavelength characteristics 224, 225, 226 and 227 of a conventional array waveguide diffraction grating type of optical wavelength multiplexer/branching filter.

0017 As shown in Fig.11 and Fig.12, the insertion losses for each output waveguide 208 are determined by the superimposed integrals of the particular modes of each output waveguide 208 and the electrical field distributions 220, 221 and 222 of the optical signals at the condensing surface. The electrical field distributions 220, 221 and 222 of the optical signals move on H-H' of condensing surface 219 according to the wavelength. The shape of the electrical distribution also becomes more asymmetric as the condensing position of the optical signal goes away from the vicinity of Y_5. As electrical field distribution shape 221 is close to being symmetrical to right and left with the condensing position in the vicinity of Y_5, there is not much change in the insertion loss even if the wavelength fluctuates a little. However, as the electrical field distribution shapes 220 and 222 are asymmetric to left and right with condensing positions in the vicinity of Y_1 and and Y_9, the insertion loss fluctuates greatly if the wavelength fluctuates. Consequently, the loss wavelength characteristic 224 of the output waveguide 208 of wavelength λ_5 becomes a flat characteristic in passing band 227. In contrast to this, the passing band characteristics of loss wavelength characteristics 225 and 226 of the output waveguides of wavelengths λ_1 and λ_9 cannot but be tilted characteristics.

0018

Problems to Be Overcome by the Invention

Thus with a conventional optical wavelength multiplexer/branching filter the passing band characteristics of the loss wavelength characteristics do not become flat on account of aberrations and suchlike in the output side slab waveguide and therefore there was the problem that insertion loss changed greatly when the wavelength of the light source fluctuated and this was not always fully satisfactory.

0019 Consequently, the purpose of this invention is to provide an optical wavelength multiplexer/branching filter where loss fluctuation with wavelength fluctuation of the light source is small and stable combining and dividing of optical signals is possible.

0020

Means of Overcoming the Problems

In order to achieve the above aim, this invention is one that provides the following optical wavelength multiplexer/branching filter.

0021 [1] An optical wavelength multiplexer/branching filter characterised in that it is an optical wavelength multiplexer/branching filter which is provided, on a substrate, with 1 or more input channel waveguides and 1 or more output channel waveguides and an array waveguide diffraction grating consisting of a plurality of channel waveguides, in which the waveguide length is sequentially made longer by the requisite length from the shortest to the longest, and a fan-shaped input side slab waveguide, which connects the said input channel waveguide and the array waveguide diffraction grating, and a fan-shaped output side waveguide, which connects the said output channel waveguide and the said array waveguide diffraction grating; and in at least 1 out of the conecting section for the said input slab waveguide and the said array waveguide diffraction grating or the connecting section for the said output side waveguide and the said array waveguide diffraction grating the spacing between the the central axis of each of the channel waveguides, which form the said array waveguide grating, and the central axes of the respective adjacent channel waveguides gradually varies across all the channel waveguides.

0022 [2] The optical wavelength multiplexer/branching filter disclosed in the said [1] where, in the said connecting section for the said input side slab waveguide and the said connecting section for the said output side slab waveguide, the said channel waveguides that form the said array waveguide diffraction grating are respectively arranged in a radiating shape along the said input side slab waveguide and the said output side slab waveguide; and the angle with respect to the prescribed datum point between the central axis of each of the said channel waveguides and the central axes of the respective adjacent channel waveguides gradually varies across all the channel waveguides.

0023 [3] The optical wavelength multiplexer/branching filter disclosed in the said [2] where, if the number of the said channel waveguides forming the said array waveguide diffraction grating is made N, the waveguide number of each of the said channels is made i and the channel waveguide number of the datum established beforehand is made j, the angle $\Delta\theta i$ with respect to the said prescribed datum point between the channel waveguide that is number i and the one that is i + 1 in the said connecting section of the said input side slab waveguide or the said output side slab waveguide is gradually varied, as shown in equation (1) below.

$$\Delta\theta i = \Delta\theta j.\{1 + \Sigma A_k.\ |i - j|k\} \ldots\ldots\ldots\ldots\ldots(1)$$

(In equation (1), A_k is a constant and k is an integer from 1~N.)

0024 [4] The optical wavelength multiplexer/branching filter disclosed in the said [3] where, in the said equation (1), the range of the pescribed constant A is made to be -0.001 $\leq A_k \leq$ 0.001 (k is an integer from 1~N).

0025 [5] The optical wavelength multiplexer/branching filter disclosed in the said [3] or [4] where, in the said equation (1), by making the number (N) of channel waveguides forming the said array waveguide diffraction grating to be 1, the said angle $\Delta\theta i$ is made to be the one shown in equation (2) below.

$$\Delta\theta i = \Delta\theta j.\{1 + A_1.\,|\,i - j\,|\,\}\ldots\ldots\ldots\ldots\ldots(2)$$

(In equation (2), A_1 is a constant and A_1 does not equal 0.)

0026

Form of Embodiment of the Invention

An explanation of a form of embodiment of this invention is given below in concrete terms, making reference to the diagrams. Fig.1 is an explanatory diagram which shows typically an array waveguide diffraction grating type of optical wavelength multiplexer/branching filter which is a form of 1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention. Fig.1(a) is a diagram of the whole. Fig.1(b) is an expanded diagram of the array waveguide diffraction grating part. Here, as an example, an optical wavelength multiplexer/branching filter for combining and dividing 9 optical signals λ_1~λ_9 ($\lambda_1 < \lambda_2 <\ldots\ldots\ldots< \lambda_8 < \lambda_9$) is shown.

0027 As shown in Fig.1(a), it is composed, on substrate 101, of input waveguide 102 and input slab waveguide 104 and array waveguide diffraction grating 106, consisting of N channel waveguides 105 made longer sequentially by length ΔL shown in the said equation (3) from the shortest one to the longest one, and 9 output waveguides 108. Furthermore, mode conversion section 103 is formed in the connecting section for input waveguide 102 with input slab waveguide 104 in order to flatten the pass band characteristics of the loss wavelength characteristics.

0028 As shown in Fig.1(b), the various channel waveguides 105 that form array waveguide diffraction grating 106 are arranged in a radiating shape in the connecting section of input slab waveguide 104 and the connecting section of output waveguide 107 with respect to datum points 109 and 110 of input slab waveguide 104 and output slab waveguide 107. The angle $\Delta\theta$ that each channel waveguide 105 forms with its respective adjacent channel waveguides gradually changes from the bottom side (the B, C side) of the array waveguide diffraction grating as one goes towards the top side (the B', C' side). Here the angle $\Delta\theta i$111, which number i channel waveguide of array waveguide diffraction grating 106 forms with the adjacent number i + 1 channel waveguide, is arranged so as to be as in equation (4) below with respect to the channel j waveguide, which is the datum, and its angular spacing $\Delta\theta j$112.

$$\Delta\theta i = \Delta\theta j.\{1 + A.\,|\,i - j\,|\}\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

(In equation (4), i is the number in the channel waveguides forming the array waveguide diffraction grating, j the datum waveguide number, A an integer and A is not equal to 0.)

0029 In this invention, the number of channel waveguides 105 that form array waveguide diffraction grating 106 was made to be 60, the specified waveguide number j to be 30 and the angular spacing $\Delta\theta_{30}$, which this number 30 channel waveguide forms with the number 31 channel waveguide, to be 0.2 (deg.). Constant A was made to be 0.0002. Moreover, as constant A has a weak correcting effect if the absolute value of its value is weak and conversely has an over-strong correcting effect if it is too big, as shown in the said equation (1), it is desirable for it to be within a range from -0.001 to 0.001.

0030 Fig.2 is an explanatory diagram showing typically the electrical field distribution in a specific region of an array waveguide diffraction grating type of optical wavelength multiplexer/branching filter, which is a form of 1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention. Fig.2(a) shows electrical field distribution 113 of the optical signal at A-A' of mode conversion section 103. Fig.2(b) shows electrical field distribution 115 at B-B' of array waveguide diffraction grating incident end 114. Fig.2(c) shows electrical field distribution field 117 at C-C' of the array waveguide diffraction grating emitting end 116.

0031 Fig.3 is an explanatory diagram that shows typically the phase distribution of the optical signal in a specified region of the array waveguide diffraction grating type of optical wavelength multiplexer/branching filter that is a form of 1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention. Fig.3(a) shows phase distribution 118 of optical signals λ_1 and λ_9 at B-B' of array waveguide diffraction grating incident end 114. Fig.3(b) shows phase distribution 119 of optical signals λ_1 and λ_9 at array waveguide diffraction grating emitting end 116.

0032 Fig.4 is an explanatory diagram showing typically the phase difference of optical signals in a specific region of the array waveguide diffraction grating type of optical wavelength multiplexer/branching filter that is a form of 1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention. Fig.4(a) shows phase difference 120 between optical signals λ_5 and λ_1. Fig.4(b), (c) and (d) respectively show the phase differences 121, 122 and 123 with optical signals λ_3 and λ_7 and λ_9.

0033 Fig.5 shows respectively the electrical field distributions 125, 126, 127. 128 and 129 of optical signals λ_1, λ_3, λ_5, λ_7 and λ_9 at condensing surface 124 of the array waveguide diffraction grating type of optical wavelength multiplexer/branching filter that is a form of 1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention. Here, the waveguide length difference ΔL of

adjacent channel waveguides of array waveguide diffraction grating 106 is set up so as to satisfy the said equation (3).

0034 An explanation is given below of the action of the optical wavelength multiplexer/branching filter of this invention, using Fig.1 and also making reference to other appropriate diagrams.

0035 Optical signals $\lambda_1 \sim \lambda_9$ are propagated in the sequence of input waveguide 102, mode conversion section 103, input slab waveguide 104, array waveguide diffraction grating 106, output slab waveguide 107 and output waveguides 108. First of all, an explanation will be made about propagation from input waveguide 102 to array waveguide incident end 114.

0036 As shown in Fig.1(a), optical signals $\lambda_1 \sim \lambda_9$, which are incident from incident end 130, are propagated from input waveguide 102 to mode conversion section 103. Optical signals $\lambda_1 \sim \lambda_9$ are formed into twin peaked electrical field distribution 113 at A-A' of mode conversion section 103.

0037 As shown in Fig.1(b), optical signals $\lambda_1 \sim \lambda_9$ are widely spread out by the effect of diffraction in input slab waveguide 104. As shown in Fig.2(b), at B-B' of array waveguide diffraction grating incident end 114 the distribution has become 115, which has maximum and minimum values.

0038 As shown in Fig.3(a), phase distribution 118 becomes a shape that has distribution 129, partially shifted by an amount π, on account of the electrical field distribution in mode conversion section 103 being made a twin peaked shape.

0039 Next, an explanation will be given about the state of the optical signal from array waveguide diffraction grating 106 to output waveguides 108. Moreover, as the state of propagation in this part differs depending on the wavelength of the optical signal, an explanation will be given first of all for λ_5, which satisfies the aforementioned equation (3) and then an explanation will be given about the other optical signals.

0040 As shown in Fig.1(b), optical signal λ_5 at B-B' of array waveguide diffraction grating incident end 114 is incident on each channel waveguide 106 *[sic – translator]*, is divided and is propagated along the interior of the respective channel waveguides. It is again focussed into one at C-C' of array waveguide diffraction grating end 116.

0041 As shown in Fig.2(c), electrical field distribution 117 becomes a shape almost the same as that of electrical field distribution 115 at B-B' of incident end 114. With regard to phase distribution 119 shown in Fig.3(b), as optical signal λ_5 satisfies the aforementioned equation (3), it is symmetrical to left

and right exactly the same as before propagation in the array waveguide diffraction grating and it becomes a distribution where the phase is partially shifted by an amount π. Consequently, as shown in Fig.1(b), optical signal λ_5 comes to a focal point at datum point 110 on output slab waveguide 117.

0042 As shown in Fig.5, the electrical field distribution 127 becomes a shape that is virtually the same as the electrical field distribution 113 in mode conversion section 103 that is shown in Fig.2(a). In addition, as shown in Fig.1(b), optical signal λ_5 is propagated along the output waveguide that is connected to datum point 110 and is emitted from the output terminal.

0043 An explanation now follows about signals other than λ_5. Here, an explanation is given as an example for the cases of optical signals λ_1, λ_3, λ_7 and λ_9. As shown in Fig.1, optical signals λ_1, λ_3, λ_7 and λ_9 are also respectively divided by array waveguide diffraction grating 106 and propagated along respective channel waveguides 105. The electrical field distribution after propagation along array waveguide diffraction grating 106 is virtually the same as for the case for optical signal λ_5.

0044 However, as shown in Fig.4(a), (b), (c) and (d), with regard to the phase distribution, this is a curved shape and it is also tilted overall. The degree of curvature and the tilt become bigger, the bigger the difference in wavelength from optical signal λ_5. The overall tilt of the phase difference is because propagation constant β has a wavelength dispersion and the condensing position differs depending on this tilt. The phase difference becomes a curved shape because the spacing of channel waveguides 105 that form array waveguide diffraction grating 106 changes overall, as shown in the aforementioned equation (4) and it has an effect which offsets the aberrations in the output slab waveguide.

0045 Consequently, the various optical signals respectively condense at points $X_1 \sim X_9$ (not shown in the diagram) on D-D' of condensing surface 124 of output slab waveguide 107. Aberrations in the electrical field distributions 125, 126, 128 and 129 are also offset and each of the signals becomers a twin peaked shape that is symmetrical to right and left. In addition, each signal is incident on the various output waveguides 108, is propagated and can be extracted separately from output end 131 *[sic – translator]*.

0046 Fig.6 is an explanatory diagram which shows typically the loss wavelength characteristics 132 *[sic – translator]* of an array waveguide diffraction grating type of optical wavelength multiplexer/branching filter, which is a form of 1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention.

0047 As shown in Fig.5 and Fig.6, the insertion loss of each output waveguide 108 is determined by the superimposed integrals of the individual modes of each output waveguide 108 and electrical field distributions 125, 126, 127, 128 and 129 of the optical signals at C-C' of condensing surface 124.

Electrical field distributions 125, 126, 127, 128 and 129 of the optical signals move on D-D' of condensing surface 124 according to the wavelength while maintaining their twin peaked shape. Because of this, even if the wavelength of the optical signal fluctuates slightly, the insertion loss does not change much. In other words, as shown in Fig.6, with regard to the loss wavelength characteristics 132 *[sic – translator]*, as passing band 133 is flat and symmetrical to right and left even if wavelength fluctuations occur within passing band 133 in wavelengths $\lambda_1 \sim \lambda_9$ of the various optical signals, the insertion loss does not increase.

0048 Moreover, the substrate used in the optical wavelength multiplexer/branching filter of this invention can be formed not only with a glass substrate but also with a semiconductor and suchlike. Furthermore, the core, cladding and buffer layer formed on substrate 101 can be made not only with a glass material but also with semiconductor material, using optically transparent material.

0049

Effect of the Invention

As has been explained above, with the optical wavelength multiplexer/branching filter of this invention aberrations in the slab waveguide are offset by optimising the layout angle of each channel waveguide of the array waveguide diffraction grating at the input slab waveguide and the output slab waveguide and flat passing band characteristics can be realised in all the output waveguides. Therefore it is possible to provide a optical wavelength multiplexer/branching filter where loss fluctuations for wavelength fluctuations in the light source are small and stable optical signal combining and dividing is possible.

0050

Brief Explanation of the Diagrams

Fig.1 is an explanatory diagram showing typically the array waveguide diffraction grating type of optical wavelength multiplexer/branching filter which is a form of 1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention. Fig.1(a) is a diagram of the whole. Fig.1(b) is an enlarged diagram of the array waveguide diffraction grating section.

Fig.2 is an explanatory diagram showing typically the electrical field distribution in a specific region of the array waveguide diffraction grating type of optical wavelength multiplexer/branching filter which is a form of 1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention. Fig.2(a) shows electrical field distribution 113 of the optical signal at A-A' of mode conversion section 103. Fig.2(b) shows electrical field distribution 115 at B-B' of array waveguide diffraction grating incident end 114. Fig.2(c) shows electrical field distribution 117 at C-C' of array waveguide diffraction grating emitting end 116.

Fig.3 is an explanatory diagram showing the optical phase distribution in a specific region of the array waveguide diffraction grating type of optical wavelength multiplexer/branching filter which is a form of

1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention. Fig.3(a) shows optical signal λ_1 and λ_9 phase distribution 118 at B-B' of array waveguide diffraction grating incident end 114. Fig.3(b) shows optical signal λ_1 and λ_9 phase distribution 119 at array waveguide diffraction grating emitting end 116.

Fig.4 is an explanatory diagram showing typically the optical phase difference in a specific region of the array waveguide diffraction grating type of optical wavelength multiplexer/branching filter which is a form of 1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention. Fig.4(a) shows phase difference 120 between optical signals λ_1 and λ_5. Fig.4(b), (c) and (d) respectively show phase differences 121, 122 and 123 between optical signal λ_5 and optical signals λ_3, λ_7 and λ_9.

Fig.5 shows respectively the electrical field distributions 125, 126, 127, 128 and 129 of optical signals λ_1, λ_3, λ_5, λ_7 and λ_9 at condensing surface 124 of the array waveguide diffraction grating type of optical wavelength multiplexer/branching filter which is a form of 1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention.

Fig.6 is an explanatory diagram showing typically loss wave characteristics 132 *[sic – translator]* of the array waveguide diffraction grating type of optical wavelength multiplexer/branching filter which is a form of 1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention.

Fig.7 is an explanatory diagram showing typically a conventional array waveguide diffraction grating type of optical wavelength multiplexer/branching filter.

Fig.8 is an explanatory diagram showing typically electrical field distribution of the optical signal in specific regions of a conventional array waveguide diffraction grating type of optical wavelength multiplexer/branching filter. Fig.8(a) shows electrical field distribution 209 of the optical signal at E-E' of mode conversion section 203. Fig.8(b) shows electrical field distribution 211 at F-F' of array waveguide diffraction grating incident end 210. Fig.8(c) shows electrical field distribution 213 at G-G' of array waveguide diffraction grating emitting end 212.

Fig.9 is an explanatory diagram showing typically the phase distribution of the optical signal in specific regions of a conventional array waveguide diffraction grating type of optical wavelength multiplexer/branching filter. Fig.9(a), 9(e) and 9(f) (sic) respectively show phase distribution 214, 215 and 216 for optical signals λ_1, λ_5 and λ_9 at G-G' of array waveguide diffraction grating emitting end 212.

Fig.10 is an explanatory diagram showing typically the difference in optical signal phase distribution in specific regions of a conventional array waveguide diffraction grating type of optical wavelength

multiplexer/branching filter. Fig 10(a) and 10(b) show difference of phase distributions 217 and 218 which are respectively the difference between phase plane 215 of optical signal λ_5 and phase planes 214 and 216 of optical signals λ_1 and λ_9.

Fig.11 is an explanatory diagram showing typically electrical field distributions 220, 221 and 222 of optical signals λ_1, λ_5 and λ_9 at H-H' of condensing surface 219 of a conventional array waveguide diffraction grating type of optical wavelength multiplexer/branching filter.

Fig.12 is an explanatory diagram showing typically loss wavelength characteristics 224, 225, 226 and 227 of a conventional array waveguide diffraction grating type of optical wavelength multiplexer/branching filter.

Explanation of the Symbols

101 substrate

102 input waveguide

103 mode conversion section

104 input slab waveguide

105 channel waveguide

106 array waveguide diffraction grating

107 output side slab waveguide

108 output waveguide

109 datum point

110 datum point

111 angle made by number i channel waveguide with number i + 1 channel waveguide

112 angle made by specified number j channel waveguide with number j + 1 channel waveguide

113 electrical field distribution of the optical signal in the mode conversion section

114 array waveguide diffraction grating incident end

115 electrical field distribution of the optical signal at the array waveguide diffraction grating incident end

116 array waveguide diffraction grating emitting end

117 electrical field distribution of the optical signal at the array waveguide diffraction grating emitting end

118 phase distribution of optical signals $\lambda_1 \sim \lambda_9$ at the array waveguide diffraction grating incident end

119 phase distribution of optical signal λ_5 at the array waveguide diffraction grating emitting end

120 difference in phase distribution of optical signal λ_5 and phase distribution of

optical signal λ_1 at the array waveguide diffraction grating emitting end

121 difference in phase distribution of optical signal λ_3 and phase distribution of optical signal λ_5 at the array waveguide diffraction grating emitting end

122 difference in phase distribution of optical signal λ_7 and phase distribution of optical signal λ_5 at the array waveguide diffraction grating emitting end

123 difference in phase distribution of optical signal λ_9 and phase distribution of optical signal λ_5 at the array waveguide diffraction grating emitting end

124 condensing surface

125 electrical field distribution of optical signal λ_1 at the condensing surface

126 electrical field distribution of optical signal λ_3 at the condensing surface

127 electrical field distribution of optical signal λ_5 at the condensing surface

128 electrical field distribution of optical signal λ_7 at the condensing surface

129 electrical field distribution of optical signal λ_9 at the condensing surface

130 focal position of optical signal λ_5

131 focal position

132 output end

133 pass band

201 substrate

202 input waveguide

203 mode conversion section

204 input slab waveguide

205 channel waveguide

206 array waveguide diffraction grating

207 output side slab waveguide

208 output waveguide

209 electrical field distribution of the optical signal in the mode conversion section

210 array waveguide diffraction grating incident end

211 electrical field distribution of the optical signal at the array waveguide diffraction grating incident end

212 array waveguide diffraction grating emitting end

213 electrical field distribution of the optical signal at the array waveguide diffraction grating emitting end

214 phase distribution of optical signal λ_1 at the array waveguide diffraction grating emitting end

215 phase distribution of optical signal λ_5 at the array waveguide diffraction grating emitting end

216 phase distribution of optical signal λ_9 at the array waveguide diffraction grating

emitting end

217 difference between the phase distribution of optical signal λ_5 and the phase distribution of optical signal λ_1 at the array waveguide diffraction grating emitting end

218 difference between the phase distribution of optical signal λ_5 and the phase distribution of optical signal λ_9 at the array waveguide diffraction grating emitting end

219 condensing surface

220 electrical field distribution of optical signal λ_1 at the condensing surface

221 electrical field distribution of optical signal λ_5 at the condensing surface

222 electrical field distribution of optical signal λ_9 at the condensing surface

223 output end

224 loss wavelength characteristics of number 5 output waveguide

225 loss wavelength characteristics of number 1 output waveguide

226 loss wavelength characteristics of number 9 output waveguide

227 passing band

228 number 5 output waveguide

[Diagram Captions]

[Fig.2] [y-axis] Electrical Field Strength

[Fig.3] [y-axis] Phase (rad)

[Fig.4] [y-axis] Phase (rad)

[Fig.5] [y-axis] Light Strength

[Fig.6] [y-axis] Loss

[Fig.8] [y-axis] Electrical Field Strength

[Fig.9] [y-axis] Phase (rad)

[Fig.10] [y-axis] Phase (rad)

[Fig.11] [y-axis] Light Strength

[Fig.12] [y-axis] Loss [x-axis] Wavelength